Sediment TMDL Development Report for Benthic Impairments in Little Otter River, Johns Creek, Wells Creek, and Buffalo Creek

Bedford City, Bedford and Campbell Counties, Virginia

Submitted by:

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List of Acronyms

BMP	Best Management Practices
BSE	Biological Systems Engineering
CBWM	Chesapeake Bay Watershed Model
COD	Chemical Oxygen Demand
CV	Coefficient of variation
DCR	Virginia Department of Conservation and Recreation
DEQ	Virginia Department of Environmental Quality
DO	Dissolved Oxygen
E&S	Erosion and Sediment Control Program (DCR)
GIS	Geographic Information Systems
LA	Load Allocation
MDL	Minimum Detection Limit, also Maximum Daily Load
MFBI	Modified Family Biotic Index
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System program (EPA)
NASS	National Agricultural Statistics Service (USDA)
NLCD	National Land Cover Dataset
NPS	Non-Point Source
NRCS	Natural Resources Conservation Service (USDA)
PEC	Probable Effect Concentrations
PReP	Pollution Response Program (DEQ)
RBP	Rapid Bioassessment Protocol
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VSCI	Virginia Stream Condition Index
VPDES	Virginia Pollutant Discharge Elimination System
VSMP	Virginia Stormwater Management Program (DCR)
VT	Virginia Tech
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation

EXECUTIVE SUMMARY

1.1. Background

TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

Impairment Listing

The subjects of this TMDL study are eight impaired stream segments in two neighboring watersheds: four segments on Little Otter River; one segment each in Johns Creek and Wells Creek, both tributary to Little Otter River; and two segments on Buffalo Creek. These impaired segments are located within the Roanoke River Basin within Bedford City and Bedford and Campbell Counties in the Commonwealth of Virginia, Figure ES-1.

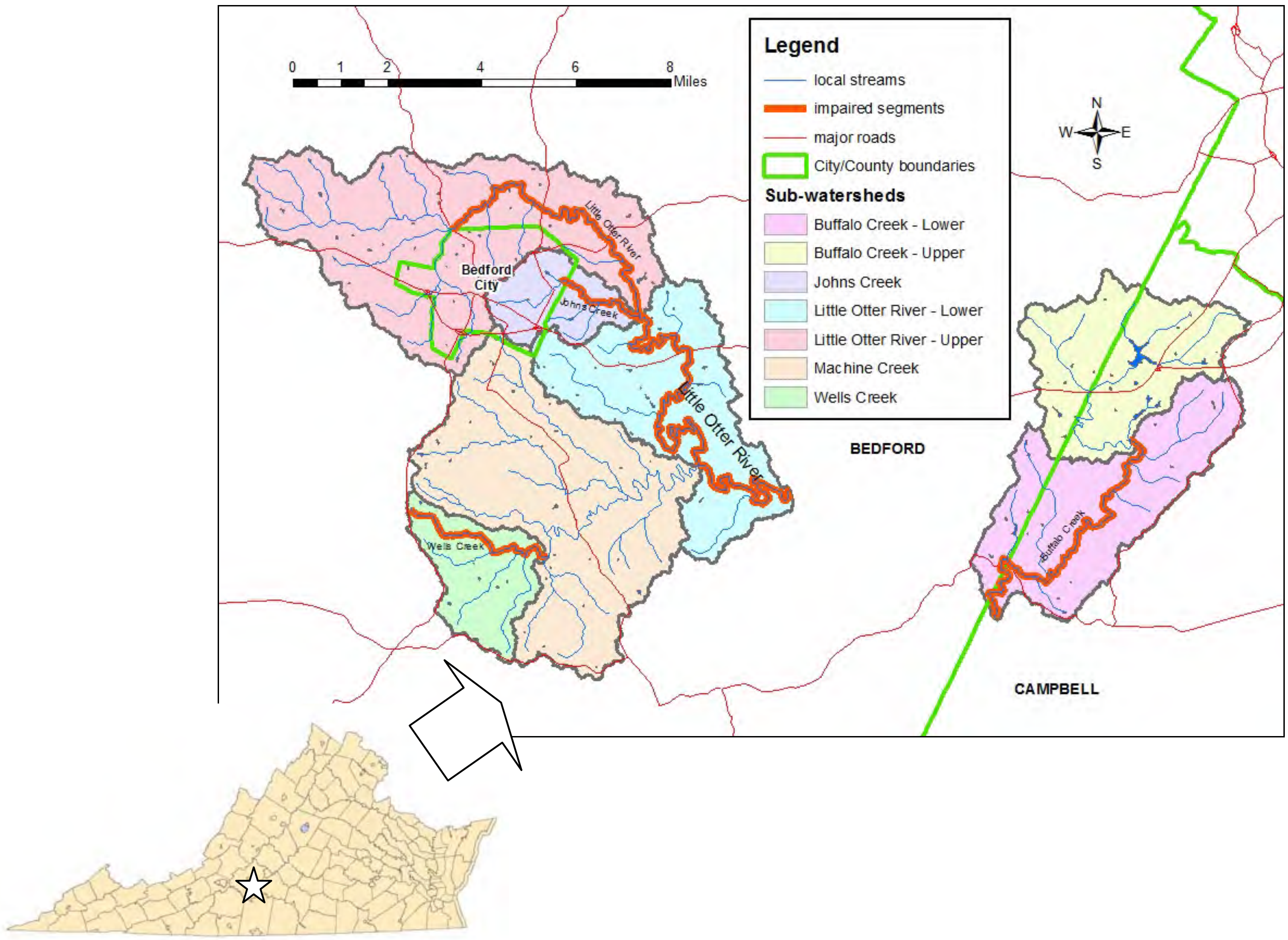


Figure ES-1. Location of Impaired Segments and Watersheds

<u>Little Otter River</u>

Little Otter River receives flow from both the Johns Creek and Wells Creek tributaries. The Little Otter Creek stream segment above the confluence with Johns Creek is referred to in this report as the Upper Little Otter River, and the Little Otter River stream segment between the confluence with Johns Creek and its downstream confluence with Big Otter River is referred to as Lower Little Otter Creek. Wells Creek is tributary to Machine Creek, which is tributary to the Lower Little Otter River.

The Upper Little Otter River was originally listed as impaired due to water quality violations of the general aquatic life (benthic) standard in the 2002 Virginia

303(d) Report (VADEQ, 2002). This impairment was based on biological monitoring at station 4ALOR014.75 and extended 5.71 miles upstream from its confluence with Johns Creek. In 2008, an additional 1.58 miles of stream was listed as impaired, extending upstream from the previous impairment for a total of 7.29 miles to its headwaters. In 2010, an impairment on the entire Lower Little Otter Creek (14.33 miles) was added based on the monitoring at stations 4ALOR012.20, 4ALOR008.64, and 4ALOR007.20, for a total combined impaired length on the Little Otter River of 21.62 miles. These impairments comprise DEQ's Cause Group Code L26R-01-BEN and consist of 4 impaired segments (VAW-L26R_LOR01A00, LOR02A00, LOR03A00, and LOR04A00). The Upper Little Otter River shows habitat impacts from sediment deposition in stream, eroded stream banks, and removal of vegetation in the riparian zone. The Lower Little Otter River shows similar habitat impacts with stream substrates embedded with fine sediments and eroding stream banks.

Johns Creek was originally listed with a benthic impairment in 2002 based on monitoring at station 4AJHN000.01. Johns Creek was listed for its entire length of 2.13 miles, from its headwaters to its confluence with Little Otter River. This impairment is listed as DEQ's Cause Group Code L26R-02-BEN and consists of just one impaired segment, VAW-L26R_JHN01A00. The stream is affected by urban and agricultural NPS pollution and flashy flows, which contribute to the erosion of its stream banks.

Wells Creek was listed initially with a benthic impairment in 2008 based on monitoring at station 4AWEL000.59. Wells Creek was listed for its entire length 3.78 miles, from its headwaters to its confluence with Machine Creek. This impairment is listed as DEQ's Cause Group Code L26R-03-BEN and consists of just one impaired segment, VAW-L26R_WEL01A02. The stream is affected by narrow riparian buffer zones and stream bank erosion, which contribute to deposition of fine sediment in the stream.

Buffalo Creek

Buffalo Creek was originally listed as impaired due to water quality violations of the general aquatic life (benthic) standard in the 2008 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report (VADEQ, 2008).

The Virginia Department of Environmental Quality (DEQ) has identified this impairment as Cause Group Code L27R-02-BEN, and delineated the benthic impairment as 8.09 miles on Buffalo Creek (stream segments VAC-L27R_BWA01A00 and VAC-L27R_BWA02A02). The Buffalo Creek impaired segments are contiguous and begin at an unnamed tributary at the Route 811 crossing in Campbell County and extend to the confluence with the Big Otter River.

The DEQ 2008 Fact Sheets for Category 5 Waters (VADEQ, 2008) state that Buffalo Creek is impaired based on assessments at biological station 4ABWA008.53. The source of impairment is described as related to the surrounding residential land uses with "increasing sedimentation and flashy flows causing erosion and nutrient enrichment."

Pollutants of Concern

Pollution from both point and nonpoint sources can lead to a violation of Virginia's General Standard (9 VAC 25-260-20). A violation of this standard is assessed on the basis of measurements of the in-stream benthic macro-invertebrate community. Water bodies having a benthic impairment are not fully supportive of the aquatic life designated use for Virginia's waters (9 VAC 25-260-10).

1.2. Benthic Stressor Analysis

TMDLs must be developed for a specific pollutant. Since a benthic impairment is based on a biological inventory, rather than on a physical or chemical water quality parameter, the pollutant is not explicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in USEPA's Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for the impaired watersheds in this study. A list of candidate causes was developed from the listing information, biological data, published literature, and stakeholder input. Chemical and physical monitoring data from DEQ provided additional evidence to support or eliminate the potential candidate causes. Biological metrics and habitat evaluations in aggregate provided the basis for the initial impairment listing, but individual metrics were also used to look for links with specific stressors, where possible. Volunteer monitoring data, land use distribution, Virginia Base Mapping Project (VBMP) aerial imagery, and visual assessment of conditions in and along the stream corridor provided additional information to investigate specific potential stressors. Logical pathways were explored between observed effects in the benthic community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause. The candidate benthic stressors considered in the following sections are ammonia, hydrologic modifications, nutrients, organic matter, pH, sediment, TDS/conductivity/sulfates, temperature, and toxics.

The Upper Little Otter River (VAW-L26R_LOR04A00) stream segment is impaired, but is on an overall increasing trend for its aquatic life use, with 2 out of 4 recent individual VSCI sample scores being in the "non-impaired" range. The Upper Little Otter River is impacted by a combination of urban and agricultural land uses. Sediment was selected as the most probable stressor based on the poor stream bank habitat scores and the evidence given by the LRBS analysis indicating excessive sediment contributions from anthropogenic sources.

The Johns Creek (VAW-L26R_JHN01A00) stream segment was severely impaired for its aquatic life use between 1997 and 2008, but has been gradually improving. Johns Creek is impacted by a combination of urban and agricultural land uses. Sediment was selected as the most probable stressor based on consistently poor scores of the habitat sediment metrics.

The Wells Creek (VAW-L26R_WEL01A02) stream segment shows impairment for its aquatic life use primarily in the springtime samples, with the most recent individual VSCI sample score in the fall being in the "non-impaired" range. Wells Creek is impacted primarily by agricultural land uses. Sediment was selected as the most probable stressor based on the poor habitat sediment metric scores and the evidence given by the LRBS analysis indicating excessive sediment contributions from anthropogenic sources.

The Lower Little Otter River (VAW-L26R_LOR01A00, VAW-L26R_LOR02A00, VAW-L26R_LOR03A00) stream segments are impaired for their aquatic life use, with the degree of impairment decreasing over time and from upstream to downstream, although the most recent samples have once again shown signs of stress. The Lower Little Otter River is impacted primarily by the WWTP effluent discharges for nutrients, with sediment coming from a combination of upstream impaired segments, instream bank and channel erosion, and land disturbance in the immediate watershed. Although the WWTP is not monitoring for nutrients at this time, it is bracketed by DEQ monitoring stations within a half mile of each other, which show increased nutrient levels at the downstream station with no other plausible source of nutrients. Therefore, the most probable stressors in this segment are both nutrients and sediment, with nutrients primarily and apparently related to WWTP effluent discharge.

The Buffalo Creek (VAC-L27R_BWA01A00, VAC-L27R_BWA02A02) stream segments are impaired for aquatic life use, with lower biological index scores in the upstream segment and with some recovery in the downstream segment, whose watershed is predominantly forested. Buffalo Creek is impacted by both urban/residential development and agricultural land uses. Sediment was selected as the most probable stressor based on the low upstream LRBS score, livestock with stream access, and the presence of many other land-disturbing activities.

In addition to the benthic impairments, these watersheds are part of the larger Big Otter River watershed, which also has a bacteria impairment addressed during a previously developed TMDL (Mostaghimi et al., 2000) and implementation plan (VT-BSE, 2006). Pollutant sources which were identified to affect the bacteria load reductions in the bacteria TMDL will also affect loads from stressors identified for the biological impairment. In particular, the bacteria TMDL calls for reductions of 85% from bacteria loads on cropland and pasture and 30%

reduction from livestock with direct stream access. Since the bacteria reductions from cropland and pasture loads relate primarily to livestock manure, they will also reduce nutrient loads from these sources. The livestock exclusion BMP will further reduce loads of nutrients and sediment.

Therefore, sediment TMDLs will be developed to address the biological impairments in Upper Little Otter River, Johns Creek, Wells Creek, the Lower Little Otter River, and Buffalo Creek. Since the source of the nutrient stressors in the Lower Little Otter River is primarily related to a permitted source, a TMDL will not be developed for TN and TP, but the impairment will instead be addressed through the permitting process.

1.3. Sediment Modeling

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutant(s) and that cause the impairment of the water body of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In the development of the sediment TMDLs for the Little Otter River and Buffalo Creek watersheds, the relationship between pollutant sources and pollutant loading to the stream was defined by land uses and areas assessed from the NASS 2009 cropland data layer, together with non-land based loads and simulated output from a computer watershed loading model.

Sediment Source Assessment

Sediment is generated in the Little Otter River and Buffalo Creek watersheds through the processes of surface runoff, in-channel disturbances, and streambank and channel erosion, as well as from natural background contributions. Sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, mining, transportation, and residential land uses.

During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to washoff during rainfall events. Sediment generated from impervious areas can be reduced through the use of management practices that reduce the surface load subject to washoff.

Permitted sediment dischargers in Buffalo Creek and Little Otter River include both stormwater and point source facilities. Stormwater discharges include construction permits regulated through Virginia's Erosion and Sediment Control Program and urban stormwater runoff from MS-4, municipal, industrial and general permits. Point source dischargers include individual VPDES facilities, as well as those that fall under the broader aggregate General Permits. All permitted stormwater and point source dischargers have requirements for installation of best management practices (BMPs) to minimize the impact of their activities on water quality.

Model Selection

The model selected for development of the sediment TMDLs in the Little Otter River and Buffalo Creek watersheds was the Generalized Watershed Loading Functions (GWLF) model, originally developed by Haith et al. (1992), with modifications by Evans et al. (2001), Yagow et al. (2002), and Yagow and Hession (2007). The model was run in metric units and converted to English units for this report.

Sub-watershed Delineation

Since simulated sediment loads were required from the comparison watersheds as well as from the watersheds corresponding to the impaired segments in the Little Otter River and Buffalo Creek, model input data were created for each of the four comparison watersheds (to be described later), for the four sub-watersheds corresponding with the impaired segments on Little Otter River and its tributaries, and for the two sub-watersheds contributing to the impaired segments on Buffalo Creek. Additionally, a portion of the Big Otter River watershed was used as a surrogate for calibrating hydrologic parameters. Model development for all watersheds was performed by assessing the sources of sediment in the watershed, evaluating the necessary parameters for modeling loads, calibrating to observed flow data, and finally applying the model and procedures for calculating loads.

Since some of the headwater watersheds are nested within downstream watersheds, the land segments were simulated uniquely, so that the land areas and associated loads do not overlap. For example, in the Buffalo Creek watershed, areas and associated loads from the Upper Buffalo Creek and Lower Buffalo Creek watersheds would need to be added together to sum for the entire watershed. Similarly in the Little Otter River watershed, the Upper Little Otter River, Johns Creek, and Wells Creek watersheds are all exclusive headwater segments, but the Lower Little Otter River receives inputs from all three, so that areas and associated loads would need to be summed for all four watersheds for totals for the Little Otter River.

The six impaired segments and their corresponding sub-watersheds are shown in Figure ES-2.

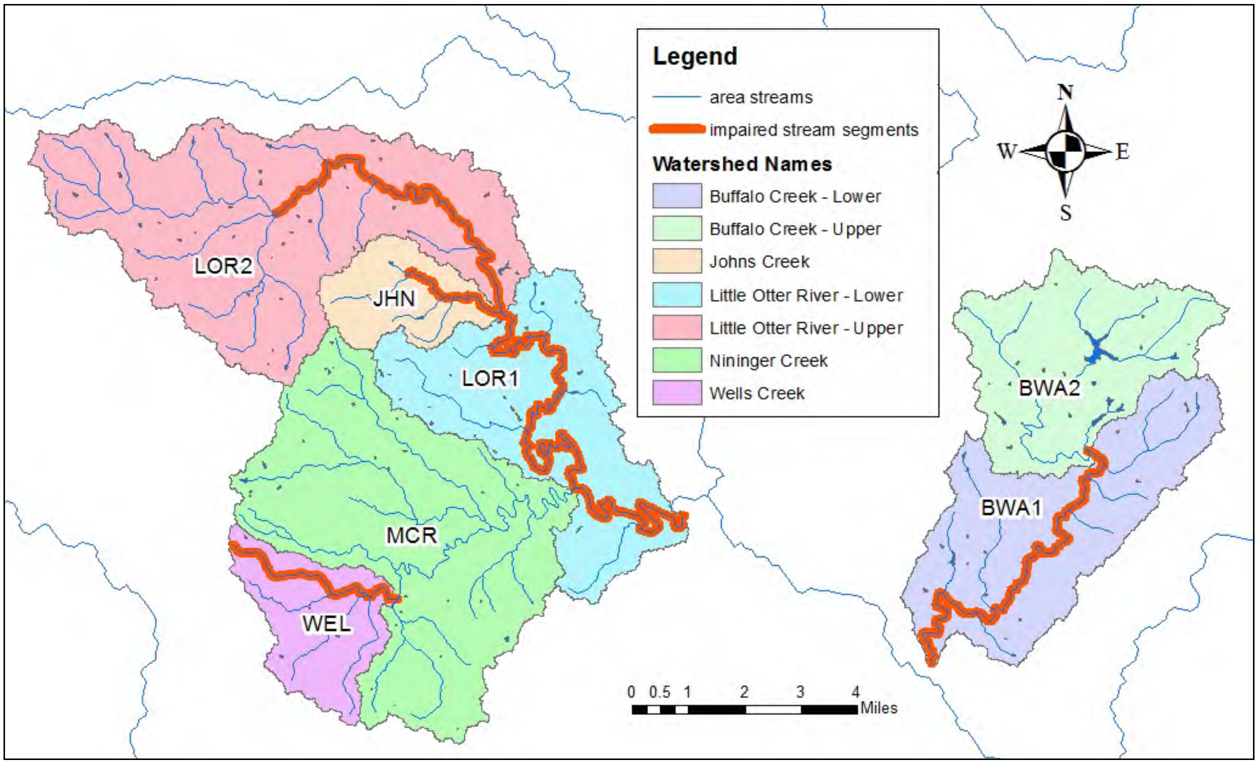


Figure ES-2. GWLF Modeling Sub-watersheds in Little Otter River and Buffalo Creek

Model Parameterization

All parameters were evaluated in a consistent manner for all watersheds in order to ensure their comparability. All GWLF parameter values were evaluated from a combination of GWLF user manual guidance (Haith et al., 1992), AVGWLF procedures (Evans et al., 2001), procedures developed during the 2006 statewide NPS pollution assessment (Yagow and Hession, 2007), and best professional judgment.

Existing land use categories were derived from the 2009 National Agricultural Statistics Service (NASS) cropland data layer, modified with information from the Conservation Tillage Information Center, the Chesapeake Bay Watershed Model, and local conservation personnel. A future land use scenario was created using the same land use categories as for the existing scenario. Future land use was assessed from a combination of the Bedford County Future Land Use spatial data layer associated with the Bedford County 2025 Comprehensive Plan, the City of Bedford 2012 Comprehensive Plan (no map), the Campbell County on-line GIS data layers for tax parcels and zoning, and the U.S. Census Bureau data for the area in both 2000 and 2010. For those areas where spatial data were available, an assessment was made of current agricultural land (agland) and forest land zoned for development. Population change between 2000 and 2010 was then evaluated. Based on a combination of the 10-yr percent change in population, the potential for future agland reduction and forest land reduction, and a visual assessment of the availability of land already sub-divided into smaller parcels (Campbell County only), percent reductions in agland and forest land were assigned to each sub-watershed.

After modeling was performed on individual and cumulative sub-watersheds, model output was post-processed in a Microsoft Excel™ spreadsheet to summarize the modeling results and to account for existing levels of BMPs already implemented within each watershed.

1.4. Accounting for Critical Conditions and Seasonal Variations

Selection of Representative Modeling Period

Selection of the modeling period was based on the availability of daily weather data and the need to represent variability in weather patterns over time in the watershed. A long period of weather inputs was selected to represent long-term variability in the watershed. The model was run using a weather time series from April 1991 through December 2010, with the first 9 months used as an initialization period for internal storages within the model. The remaining 19-year period was used to calculate average annual sediment loads in all watersheds.

Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was chosen as a multi-year period that was representative of typical weather conditions for the area, and included “dry”, “normal” and “wet” years. The model, therefore, incorporated the variable inputs needed to represent critical conditions during low flow - generally associated with point source loads – and critical conditions during high flow – generally associated with nonpoint source loads.

Seasonal Variability

The GWLF model used for this analysis considered seasonal variation through a number of mechanisms. Daily time steps were used for weather data and water balance calculations. The model also used monthly-variable parameter inputs for evapo-transpiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients for user-specified growing season months.

1.5. Model Calibration of Hydrology

Model calibration is the process of adjusting model parameter values so that simulated loads from a watershed match loads calculated from corresponding monitored ("observed") flow and concentrations at a given point in a stream. Although GWLF was originally developed for use in non-gaged watersheds and, therefore, does not require calibration, hydrologic calibration has been recommended where observed flow data is available (Dai et al., 2000). In-stream observed discharge data were not available in any of the Little Otter River or Buffalo Creek sub-watersheds, but were available in a similar-sized neighboring watershed, the Big Otter River. Hydrologic calibration was performed using this surrogate watershed, and the calibration adjustments applied to all of the Little Otter River, Buffalo Creek and comparison watersheds for the TMDL modeling.

The monthly runoff time series for Big Otter River showed a generally good correspondence between observed and simulated monthly runoff, with a correlation coefficient of 0.89. The simulated seasonal percentages of runoff varied up to 38% of the observed values (mainly due to a mismatch of observed and simulated data in September 2010), although total simulated runoff was only 0.5% less than the observed value. The difference between observed and simulated individual season average annual discharge totals were within ±1.73 cm/season, and the baseflow percentage was within 11.5% of observed baseflow, calculated using the baseflow separation routine of Arnold et al. (1995).

Since the TMDL is based on long-term average annual loads and uses comparably parameterized watersheds, the calibrated GWLF model should provide reasonable load comparisons for TMDL development.

1.6. Simulated Sediment Loads

Existing Sediment Loads

Existing sediment loads were simulated for all individual land uses with the calibrated GWLF model and calculated for point sources, as discussed previously. The resulting loads in all impaired and comparison watersheds are given in Table ES-1.

Table ES-1. Existing Sediment Loads in Impaired and Comparison Watersheds

Land Use/Source Categories	Impaired Watersheds							Comparison Watersheds			
	BWA1	**BWA2**	**LOR1**	**MCR**	**WEL**	**JHN**	**LOR2**	**BLD**	**BNF**	**CNT**	**GCR**
	Lower Buffalo Creek	**Upper Buffalo Creek**	**Lower Little Otter River**	**Machine Creek**	**Wells Creek**	**Johns Creek**	**Upper Little Otter River**	**Buffalo Creek (BLD)**	**NF Buffalo River**	**Big Chestnut Creek**	**Green Creek**
	Sediment Load (tons/yr)										
HiTill Rowcrop (hit)	12.2	44.7	96.7	76.1	1.8	4.7	8.0	26.8	0.0	510.3	1.3
LoTill Rowcrop (lot)	2.1	7.7	92.2	72.9	1.7	4.5	7.7	170.7	0.0	263.9	0.7
Pasture (pas_g)	24.7	9.4	65.8	28.9	32.5	3.1	53.4	198.7	0.0	52.4	2.8
Pasture (pas_f)	869.2	332.0	2,368.4	1,078.4	1,060.2	109.8	1,887.9	6,488.7	1.4	1,723.4	92.4
Pasture (pas_p)	492.6	192.1	1,363.3	622.1	608.8	63.9	1,087.7	3,714.1	0.8	981.2	53.9
Riparian pasture (trp)	1,124.3	436.8	3,320.7	1,551.4	1,385.5	144.0	2,576.1	8,135.3	1.4	2,225.2	121.5
AFO (afo)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay (hay)	298.0	145.1	1,259.1	782.2	308.5	52.0	689.1	2,041.5	0.5	849.4	50.2
Forest (for)	145.8	26.8	184.4	98.6	18.9	16.4	97.6	2,136.3	388.1	696.0	456.5
Harvested forest (hvf)	13.4	2.5	16.2	8.9	1.7	1.5	8.9	176.1	32.7	60.5	40.0
Transitional (barren)	259.7	169.2	152.6	53.4	11.9	59.6	165.6	235.4	8.4	63.8	26.6
Pervious LDI (pur_LDI)	76.8	163.6	198.8	102.9	23.8	95.1	299.3	844.9	36.2	211.8	135.0
Pervious MDI (pur_MDI)	0.2	4.6	1.6	0.3	0.0	7.9	8.6	0.9	0.0	2.0	0.0
Pervious HDI (pur_HDI)	0.0	0.4	0.0	0.0	0.0	1.1	0.9	0.0	0.0	0.2	0.0
Impervious LDI (imp_LDI)	9.0	16.8	40.3	6.6	0.7	9.7	30.3	14.4	0.0	7.2	0.0
Impervious MDI (imp_MDI)	10.4	26.5	47.3	0.7	0.0	26.7	38.8	2.5	0.0	9.3	0.0
Impervious HDI (imp_HDI)	2.2	4.9	13.6	0.2	0.0	10.0	8.5	0.2	0.0	1.4	0.0
Channel Erosion	30.2	14.3	306.4	38.4	2.7	6.4	55.4	615.2	3.2	324.1	2.3
Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	0.0	0.0	0.0
Total Sediment Load	**3,370.8**	**1,597.4**	**9,527.3**	**4,522.1**	**3,458.8**	**616.3**	**7,035.3**	**24,801.8**	**472.6**	**7,982.0**	**983.3**

Future Sediment Loads

Future sediment loads were simulated for all land use categories with the calibrated GWLF model with point sources calculated at their permit limits, as discussed previously. Since future sediment loads are considered to be the starting loads from which reductions will be required to meet the TMDLs, modeling of the future land uses was only performed on the impaired watersheds.

The resulting future loads of sediment, shown in Table ES-2 are simulated as decreasing slightly from existing conditions based on the assessed future land use changes from agriculture to developed land uses.

Table ES-2. Future Sediment Loads in Impaired Watersheds

Land Use/Source Categories	Impaired Watersheds						
	BWA1f	**BWA2f**	**LOR1f**	**MCR**	**MCRf**	**JHNf**	**LOR2f**
	Lower Buffalo Creek	**Upper Buffalo Creek**	**Lower Little Otter River**	**Machine Creek**	**Wells Creek**	**Johns Creek**	**Upper Little Otter River**
	Sediment Load (tons/yr)						
HiTill Rowcrop (hit)	11.8	44.7	99.2	73.8	1.8	4.2	6.7
LoTill Rowcrop (lot)	2.1	7.7	94.6	70.8	1.7	4.0	6.5
Pasture (pas_g)	23.7	9.4	65.0	27.5	32.5	2.8	44.9
Pasture (pas_f)	833.5	332.0	2,342.6	1,030.2	1,060.2	97.7	1,585.4
Pasture (pas_p)	472.3	192.1	1,348.6	594.3	608.8	56.9	913.4
Riparian pasture (trp)	1,077.8	436.9	3,263.6	1,485.2	1,385.5	128.1	2,163.3
AFO (afo)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay (hay)	284.8	145.1	1,223.6	757.6	308.5	46.3	578.7
Forest (for)	118.4	24.1	180.4	96.6	18.9	13.1	83.9
Harvested forest (hvf)	10.9	2.2	15.9	8.7	1.7	1.2	7.7
Transitional (barren)	469.6	182.7	195.8	70.6	11.9	71.1	255.3
Pervious LDI (pur_LDI)	194.3	178.3	248.4	127.9	23.8	106.0	459.7
Pervious MDI (pur_MDI)	3.8	1.5	1.8	0.4	0.0	9.5	13.4
Pervious HDI (pur_HDI)	0.1	0.5	0.0	0.1	0.0	1.3	1.3
Impervious LDI (imp_LDI)	14.9	18.2	53.6	6.4	0.7	9.7	45.9
Impervious MDI (imp_MDI)	16.2	25.5	61.6	0.9	0.0	32.0	60.2
Impervious HDI (imp_HDI)	3.6	6.6	17.5	0.2	0.0	12.0	13.2
Channel Erosion	130.5	15.4	302.2	34.6	2.7	9.2	56.9
Permitted WLA	4.2	9.1	12.1	11.7	0.2	11.1	99.3
Total Sediment Load	**3,672.4**	**1,632.0**	**9,526.5**	**4,397.5**	**3,458.8**	**615.9**	**6,395.5**

1.7. The Sediment TMDLs

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that appropriate actions can be taken to achieve water quality standards (USEPA, 1991). The stressor analysis in each of the Buffalo Creek and Little Otter River watersheds Creek indicated that sediment was the "most probable stressor", and therefore, sediment will serve as the basis for development of these TMDLs.

Setting the TMDL Endpoint and MOS using the AllForX Approach

Since there are no in-stream water quality standards for sediment in Virginia, an alternate method was needed for establishing a reference endpoint that would represent the "non-impaired" condition.

For the Little Otter River and Buffalo Creek impairments, the procedure used to set TMDL sediment endpoint loads is a modification of the methodology used to address sediment impairments in Maryland's non-tidal watersheds (MDE, 2006, 2009), hereafter referred to as the "all-forest load multiplier", or the AllForX, approach. The AllForX approach was modified and adapted for a localized application based on a regression of the Virginia Stream Condition Index (VSCI) biological index scores from the impaired watersheds and a selection of multiple healthy comparison watersheds and their corresponding all-forest load multipliers (AllForX), a unit-less measure that represents the magnitude of the existing load beyond that of an all-forest condition.

The sediment TMDL load for each impaired watershed was calculated as the value of AllForX at the VSCI impairment threshold (VSCI < 60) times the all-forest sediment load of the impaired watershed. Since a number of watersheds are used to set the regression, a confidence interval around the threshold was quantified and used to calculate the margin of safety in the Total Maximum Daily Load equation. This approach is an improvement over the reference watershed approach as the sediment endpoint is directly linked with the biological index. The relationship between AllForX and the biological condition is further validated with plots and regressions between AllForX and various independent sediment-related habitat metrics.

The selected comparison watersheds were nearby watersheds that have healthy biological communities as measured by the VSCI. These comparison watersheds were generally 1st - 3rd order streams with multiple DEQ biological samples. Four comparison watersheds were identified for application of the AllForX approach with the Little Otter River and Buffalo Creek watersheds, as shown in Figure ES-3.

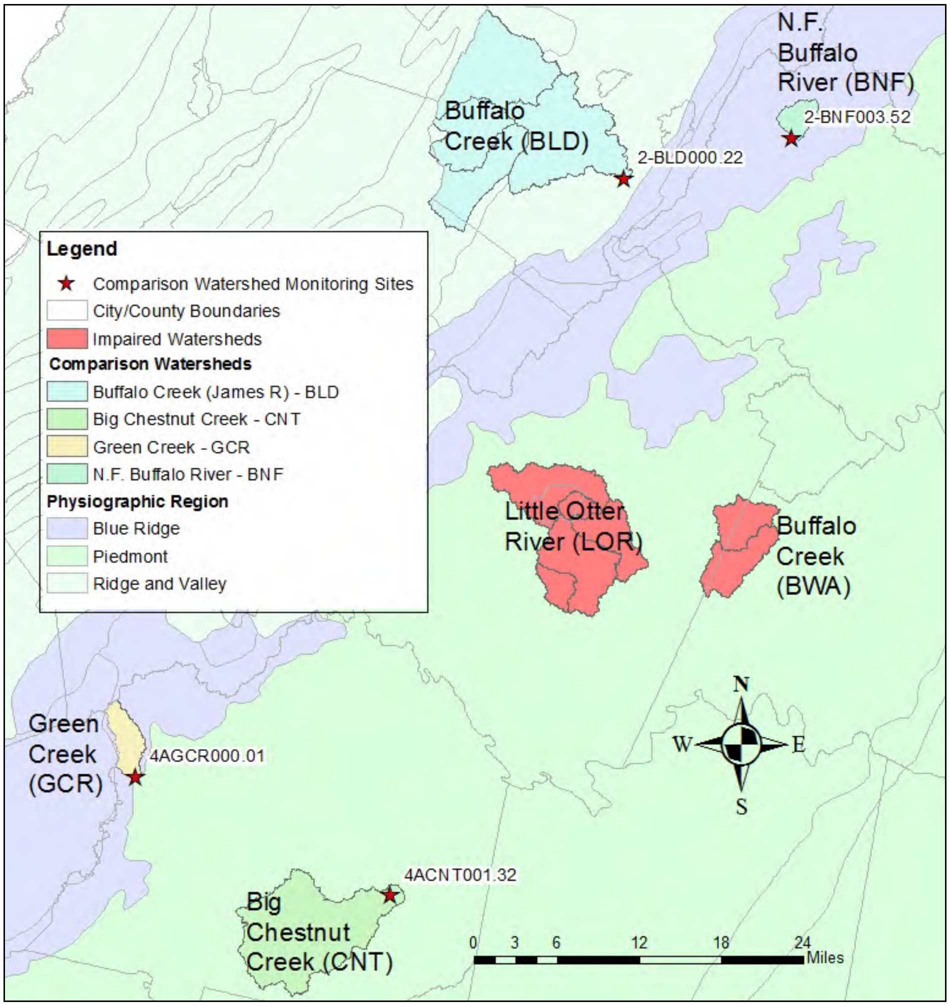


Figure ES-3. Location of Impaired and Comparison Watersheds

In the AllForX approach, the metric used for setting a numeric sediment threshold is the All-Forest Load Multiplier (AllForX) calculated as the existing sediment load normalized by the corresponding load under an all-forest condition. AllForX is calculated as the existing sediment load in any given watershed divided by the corresponding sediment load simulated under an all-forest condition. When AllForX is regressed against VSCI for a number of healthy watersheds that surround a particular impaired watershed or set of impaired watersheds, the developed relationship can be used to quantify the value of AllForX for the biological health threshold (VSCI < 60) used to assess aquatic life use impairments in Virginia. The sediment TMDL load is then calculated as the value of AllForX at the VSCI threshold times the all-forest sediment load of the impaired watershed. Since a number of watersheds are used to quantify the regression, a confidence interval around the threshold could be calculated and was used to quantify the margin of safety in the Total Maximum Daily Load equation.

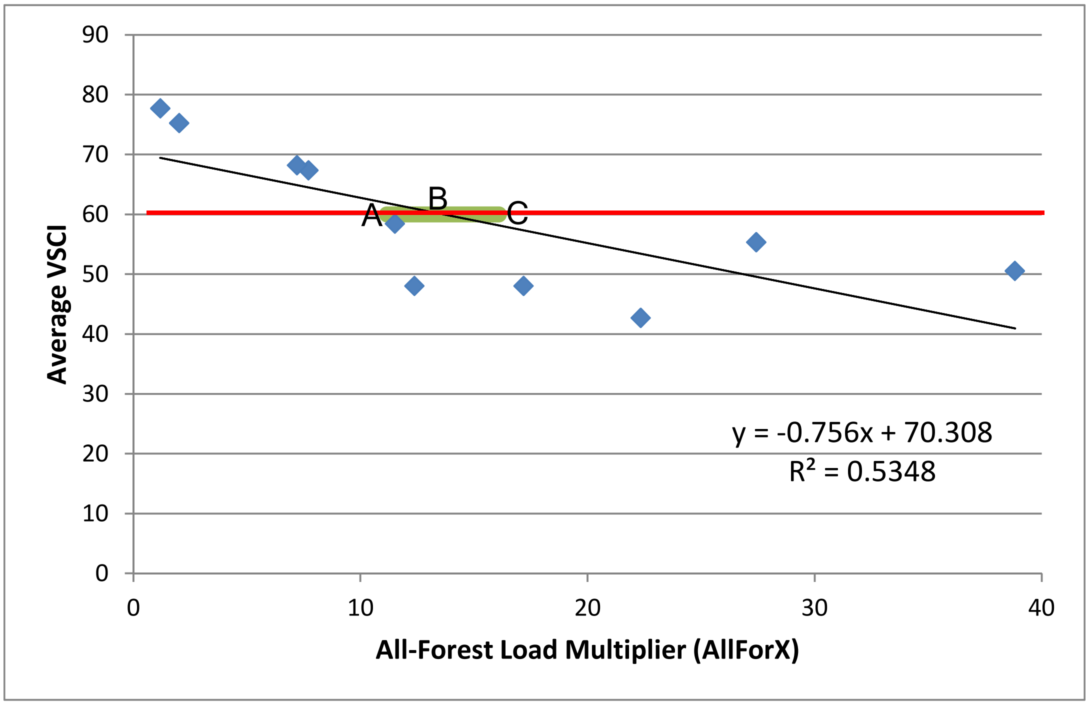
Existing sediment loads were calculated for each of the watersheds contributing to the six (6) impaired segments in this study and for each of the four (4) comparison watersheds. A modeling scenario was then created and run, which substituted forest land use-related parameters for each of the other land uses, while preserving the unique characteristics of soil and slope distributions across each watershed. AllForX was then calculated by dividing existing sediment loads by the corresponding all-forest load. The modeling results for each watershed are summarized as long-term averages for each watershed in Table ES-3.

Table ES-3. Metrics used in the AllForX Approach

	Impaired Watersheds							Comparison Watersheds			
	BWA1	**BWA2**	**LOR1**	**MCR**	**WEL**	**JHN**	**LOR2**	**BLD**	**BNF**	**CNT**	**GCR**
	Sediment Load in tons/yr										
Existing Sediment Load	3,370.8	1,597.4	9,527.3	4,522.1	3,458.8	616.3	7,035.3	24,801.8	472.6	7,982.0	983.3
All-Forested Sediment Load	292.4	71.5	769.1	302.3	89.1	35.8	256.4	0.0	3,210.9	398.6	1,106.4
AllForX*	**11.5**	**22.3**	**12.4**		**38.8**	**17.2**	**27.4**	**7.7**	**1.2**	**7.2**	**2.0**
Average VSCI	**58.4**	**42.7**	**48.0**	**0.0**	**50.5**	**48.0**	**55.3**	**67.3**	**77.7**	**68.2**	**75.2**

A regression between AllForX and VSCI was developed using all ten (10) watersheds, as shown in Figure ES-4. The value of AllForX used to set the sediment TMDL load was the value where the regression line crossed the biological impairment threshold of VSCI = 60 (AllForX = 13.64), indicated by point B. The TMDL load for each watershed was calculated as its All-Forest sediment load times the threshold AllForX value (13.64). An 80% confidence interval was then calculated around the point where the regression line intersects the biological impairment threshold (VSCI = 60). The margin of safety (MOS) was calculated as the All-Forest sediment load times the difference in AllForX between the point where the regression crosses VSCI = 60 (AllForX = 13.64) and the lower bound of the 80% confidence interval (AllForX = 11.17). Note that the MOS is equal to this difference expressed as a percentage of the threshold AllForX, and therefore is the same for all watersheds using this regression.

Existing, TMDL, and MOS loads are shown in Table ES-4 for each impaired segment. Since the MOS is a measure of uncertainty in the TMDL, the implementation target load is the TMDL minus the MOS, and the percent reduction is calculated as the change from the future load to the allocation target load.



B = AllForX value used for the TMDL; AC = the 80% Confidence Interval (shown in green);
B - A = AllForX value used for the MOS; A = AllForX value used for the target allocation load.

Figure ES-4. Regression and AllForX Threshold for Sediment in Little Otter and Buffalo Creek

Table ES-4. Calculation of the TMDL and MOS for each Impaired Segment

	Impaired Watersheds					
	BWA1	**BWA2**	**LOR1**	**WEL**	**JHN**	**LOR2**
Future Sediment Load	3,672.4	1,632.0	9,526.5	3,458.8	615.9	6,395.5
All-Forested Sediment Load	292.4	71.5	769.1	89.1	35.8	256.4
TMDL Load (AllForX = 13.64)	**3,987.4**	**974.8**	**10,487.3**	**1,214.7**	**488.8**	**3,496.4**
Margin of Safety (MOS)*	**721.3**	**176.3**	**1,897.0**	**219.7**	**88.4**	**632.5**
MOS as % of TMDL	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%
Allocation Load (TMDL - MOS)	**3,266.1**	**798.5**	**8,590.3**	**995.0**	**400.4**	**2,864.0**
% Reduction from Future Load:	11.1%	51.1%	9.8%	71.2%	35.0%	55.2%

* MOS = (AllForX$_{13.64}$ - AllForX$_{11.17}$) * All-Forest Load

Buffalo Creek and Little Otter River Sediment TMDLs

The sediment TMDL for each of the Buffalo Creek and Little Otter River watersheds was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

where $\sum WLA$ = sum of the wasteload (permitted) allocations;

$\sum LA$ = sum of load (nonpoint source) allocations; and

MOS = margin of safety.

The TMDL sediment loads for each impaired watershed were calculated using the AllForX method.

The WLA in each watershed is comprised of sediment loads from a number of individual industrial stormwater, municipal, and commercial permitted sources, as well as aggregated loads from construction runoff in each watershed. In addition, a Future Growth WLA was calculated as a portion of existing WLAs in each watershed, excluding construction, plus a portion of existing WWTP WLAs, with a minimum allowance of 0.1% of the TMDL.

An explicit MOS was calculated for each impaired watershed also using the AllForX method.

The LA was calculated as the TMDL minus the sum of WLA and MOS. The TMDL load and its components for each impaired watershed are shown in Table ES-5.

Table ES-5. Buffalo Creek and Little Otter River Sediment TMDLs

Impairment	TMDL	WLA		LA	MOS
	(tons/yr)				
Cause Group Code L27R-02-BEN					
Lower Buffalo Creek	3,987.4	11.45		3,254.6	721.3
VAC-L27R_BWA02A02		VAR051801 New London Auto Parts Inc	3.64 tons/yr		
VAC-L27R_BWA01A00		construction aggregate WLA	0.53 tons/yr		
		Future Growth WLA	7.28 tons/yr		
Upper Buffalo Creek	974.8	22.99		775.4	176.3
		VAR040115 Virginia DOT MS-4 WLA	6.95 tons/yr		
		construction aggregate WLA	2.13 tons/yr		
		Future Growth WLA	13.91 tons/yr		
Cause Group Code L26R-01-BEN					
Lower Little Otter River	10,487.3	34.50		8,555.9	1,897.0
VAW-L26R_LOR01A00		VAR051233 Bedford County - Sanitary Landfill	11.22 tons/yr		
VAW-L26R_LOR02A00		construction aggregate WLA	0.84 tons/yr		
VAW-L26R_LOR03A00		Future Growth WLA	22.45 tons/yr		
Upper Little Otter River	3,496.4	158.23		2,705.7	632.5
VAW-L26R_LOR04A00		VA0022390 Bedford City - WWTP	91.38 tons/yr		
		VAG640066 Bedford City - WTP	1.51 tons/yr		
		VAR050544 Hilltop Lumber Co Inc	2.56 tons/yr		
		VAR052107 Central VA Pallet and Stake Co	2.53 tons/yr		
		construction aggregate WLA	1.36 tons/yr		
		Future Growth WLA	58.89 tons/yr		
Cause Group Code L26R-02-BEN					
Johns Creek	488.8	32.12		368.3	88.4
VAW-L26R_JHN01A00		VAG110014 Bedford Ready Mix Concrete	0.33 tons/yr		
		VAR050528 Sam Moore Furniture LLC	4.32 tons/yr		
		VAR050733 Rubatex International LLC	1.57 tons/yr		
		VAR051369 Bedford City - Hylton Site	4.32 tons/yr		
		construction aggregate WLA	0.53 tons/yr		
		Future Growth WLA	21.06 tons/yr		
Cause Group Code L26R-03-BEN					
Wells Creek	1,214.7	1.40		993.6	219.7
VAW-L26R_WEL01A02		VA0020818 Body Camp Elementary School	0.1 tons/yr		
		construction aggregate WLA	0.09 tons/yr		
		Future Growth WLA	1.21 tons/yr		

1.8. Allocation Scenarios

The target allocation sediment load for each watershed allocation scenario is the TMDL minus the MOS. Allocation scenarios were created by applying percent reductions to the various land use/source categories sufficient to achieve the target allocation load for each of the Buffalo Creek and Little Otter River watersheds.

Two allocation scenarios were created for each of the watersheds. Scenario 1 applies equal percent reductions from all land uses and sources, except forest and point sources. Scenario 2 applies equal percent reductions from only the two largest sources in each watershed. The preferred scenario for each watershed will be determined by the local Technical Advisory Committee. Future sediment loads along with two allocation scenarios are presented by grouped land uses and sources for the Lower Buffalo Creek in Table ES-6; Upper Buffalo Creek in Table ES-7; for the Lower Little Otter River in Table ES-8; for Johns Creek in Table ES-9; for Wells Creek in Table ES-10; and for the Upper Little Otter River in Table ES-11.

Table ES-6. Sediment TMDL Load Allocation Scenario, Lower Buffalo Creek

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	13.9	11.4%	12.3		13.9
Pasture	2,407.3	11.4%	2,131.7	13.1%	2,092.7
Hay	284.8	11.4%	252.2		284.8
Forest	118.4		118.4		118.4
Harvested Forest	10.9	11.4%	9.7		10.9
Developed	702.6	11.4%	622.2	13.1%	610.8
Channel Erosion	130.5	11.4%	115.5		130.5
Permitted WLA	4.2		4.2		4.2
Total Load	3,672.4		**3,266.1**		**3,266.1**
Target Allocation Load	**3,266.1**				
% Reduction Needed :	11.1%				

Table ES-7. Sediment TMDL Load Allocation Scenario, Upper Buffalo Creek

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	52.4	52.1%	25.1		52.4
Pasture	970.4	52.1%	464.5	60.2%	385.9
Hay	145.1	52.1%	69.4		145.1
Forest	24.1		24.1		24.1
Harvested Forest	2.2	52.1%	1.1		2.2
Developed	413.3	52.1%	197.8	60.2%	164.3
Channel Erosion	15.4	52.1%	7.4		15.4
Permitted WLA	9.1		9.1		9.1
Total Load	1,632.0		**798.5**		**798.5**
Target Allocation Load	**798.5**				
% Reduction Needed :	51.1%				

Table ES-8. Sediment TMDL Load Allocation Scenario, Lower Little Otter River

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	193.8	10.0%	174.4		193.8
Pasture	7,019.9	10.0%	6,315.8	12.3%	6,155.0
Hay	1,223.6	10.0%	1,100.9		1,223.6
Forest	180.4		180.4		180.4
Harvested Forest	15.9	10.0%	14.3		15.9
Developed	578.7	10.0%	520.7	12.3%	507.4
Channel Erosion	302.2	10.0%	271.9		302.2
Permitted WLA	12.1		12.1		12.1
Total Load	9,526.5		**8,590.3**		**8,590.3**
Target Allocation Load	**8,590.3**				
% Reduction Needed	9.8%				

Table ES-9. Sediment TMDL Load Allocation Scenario, Johns Creek

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	8.1	36.4%	5.2		8.1
Pasture	285.4	36.4%	181.5	40.9%	168.7
Hay	46.3	36.4%	29.4		46.3
Forest	13.1		13.1		13.1
Harvested Forest	1.2	36.4%	0.8		1.2
Developed	241.6	36.4%	153.6	40.9%	142.8
Channel Erosion	9.2	36.4%	5.9		9.2
Permitted WLA	11.1		11.1		11.1
Total Load	615.9		**400.4**		**400.4**
Target Allocation Load	**400.4**				
% Reduction Needed	35.0%				

Table ES-10. Sediment TMDL Load Allocation Scenario, Wells Creek

Land Use/ Source Group	Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	3.6	71.6%	1.0		3.6
Pasture	3,087.0	71.6%	875.8	78.9%	651.8
Hay	308.5	71.6%	87.5		308.5
Forest	18.9		18.9		18.9
Harvested Forest	1.7	71.6%	0.5		1.7
Developed	36.3	71.6%	10.3	78.9%	7.7
Channel Erosion	2.7	71.6%	0.8		2.7
Permitted WLA	0.2		0.2		0.2
Total Load	3,458.8		**995.0**		**995.0**
Target Allocation Load	**995.0**				
% Reduction Needed	71.2%				

Table ES-11. Sediment TMDL Load Allocation Scenario, Upper Little Otter River

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	13.2	56.8%	5.7		13.2
Pasture	4,706.9	56.8%	2,031.2	63.6%	1,715.0
Hay	578.7	56.8%	249.7		578.7
Forest	83.9		83.9		83.9
Harvested Forest	7.7	56.8%	3.3		7.7
Developed	848.9	56.8%	366.3	63.6%	309.3
Channel Erosion	56.9	56.8%	24.5		56.9
Permitted WLA	99.3		99.3		99.3
Total Load	6,395.5		**2,864.0**		**2,864.0**
Target Allocation Load	**2,864.0**				
% Reduction Needed :	55.2%				

1.9. Lower Little Otter Creek Nutrient Impairment

Nutrients have been diagnosed as one of the most probable stressors in the Lower Little Otter River. Specifically, between DEQ monitoring stations 4ALOR014.75 and 4ALOR014.33, average total nitrogen increases from 0.9 to 3.4 mg/L and average total phosphorus increases from 0.1 to 0.7 mg/L. The most apparent source of these nutrients is the discharge from a permitted point source, VA0022390 – the Bedford City wastewater treatment plant. Frequent exceedences of the in-stream TP threshold of 0.2 mg/L have been noted at the downstream DEQ monitoring station, although TP is not one of the permit parameters required at the effluent outfall.

The Little Otter River is a tributary to Smith Mountain Lake, and as such is subject to regulation 9VAC25-40-30 for "nutrient enriched waters" outside of the Chesapeake Bay Watershed. All dischargers in these waters authorized by VPDES permits for discharges of 1.0 MGD or more are required to meet a monthly average total phosphorus effluent limitation of 2.0 mg/l.

Since the source of the nutrient stressors in the Lower Little Otter River is related to a permitted source, a TMDL will not be developed for TN and TP, but the impairment will instead be addressed through the permitting process. Additional effluent monitoring is recommended to ensure compliance with the “nutrient enriched waters” limitation.

1.10. Reasonable Assurance for Implementation

TMDL Monitoring

DEQ will monitor benthic macro-invertebrates and habitat in accordance with its biological monitoring program, and TSS in accordance with its ambient monitoring program at station 4ALOR014.75 in the Upper Little Otter River, at station 4AJHN000.01 in Johns Creek, at station 4AWEL001.14 in Wells Creek, at station 4ALOR014.33 in the Lower Little Otter River, at station 4ABWA008.53 in the Upper Buffalo Creek, and at station 4ABWA002.00 in the Lower Buffalo Creek. In the past, all of these stations have been used for both biological and ambient sampling, with the exception of stations 4ALOR014.33 and station 4ABWA008.53 which were monitored regularly for benthic macro-invertebrates and habitat, but only periodically for ambient parameters. DEQ will add bi-monthly sampling of ambient TSS at these two stations and will continue to use data from all of these monitoring stations to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

Regulatory Framework

Federal Regulations

While section 303(d) of the Clean Water Act and current USEPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Federal regulations also require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to USEPA for review.

State Regulations

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section

62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. USEPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and implementation plan development, especially those implemented through water quality based effluent limitations. However, those requirements that are considered BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the identified impairment. New permitted point source discharges will be allowed under the waste load allocation provided they implement applicable VPDES requirements.

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairments on Buffalo Creek, Johns Creek, Wells Creek, and Little Otter River. The second step is to develop a TMDL Implementation Plan. The final step is to implement the TMDL Implementation Plan and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by USEPA and then the State Water Control Board (SWCB), measures must be taken to reduce pollutant levels in the stream. These measures, which can include the use of better treatment technology and the installation of BMPs, are implemented in an iterative process that is described along with specific BMPs in the Implementation Plan. The process for developing an Implementation Plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/ipguide.pdf. With successful completion of Implementation Plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved Implementation Plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

DCR and DEQ will work closely with watershed stakeholders, interested state agencies, and support groups to develop an acceptable Implementation Plan that will result in meeting the water quality target. Stream delisting of Buffalo Creek and Little Otter River impaired stream segments will be based on biological health and not on numerical pollution loads.

Implementation of BMPs to address the benthic impairments in Buffalo Creek and Little Otter River will be coordinated with BMPs required to meet bacteria water quality standards in a previous TMDL developed for the Big Otter River watershed, which includes both Buffalo Creek and Little Otter River.

Reasonable Assurance Summary

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between USEPA and DEQ, DEQ also submitted a draft Continuous Planning Process to USEPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Taken together, the follow-up monitoring, WQMIRA, public participation, the Continuing Planning Process, and the reductions called for in the concurrent bacteria TMDL on the Big Otter River comprise a reasonable assurance that the Buffalo Creek, Johns Creek, Wells Creek, and Little Otter River sediment TMDLs will be implemented and water quality will be restored.

1.11. Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made.

The first Technical Advisory Committee Meeting was held from 10:00 am until noon on June 21, 2012 at the Bedford Central Library in Bedford, Virginia. The purpose of that meeting was to introduce agency stakeholders to the TMDL process and to discuss the impairments identified on stream segments in these watersheds. The public meeting was attended by 19 people. Many of the attendees reconvened after lunch to participate in a watershed tour, conducted by personnel from the Peaks of Otter Soil and Water Conservation District and NRCS personal.

The first Public Meeting was held at 7:00 – 9:00 pm at the Forest Library in Forest, Virginia on August 14, 2012, where the TMDL process was introduced, local stream impairments were presented, and comments were solicited from the stakeholder group. The first public meeting was attended by 18 people.

A second Technical Advisory Committee meeting was held from 2:00 – 4:00 pm on October 18, 2012, at the Bedford Central Library in Bedford. The results from the stressor analysis were presented, and comments were solicited from the stakeholder group. The second TAC meeting was attended by 9 people.

A third Technical Advisory Committee meeting is planned for February 7, 2013 to present modeling procedures, draft modeling results, and to solicit feedback on the proposed TMDL strategy.

A final public meeting is planned for February 20, 2013 to present the draft TMDL report to address benthic impairments in the Little Otter River and Buffalo Creek watersheds. This final TMDL public meeting was attended by xx stakeholders. The public comment period will end on March xx, 2013.

Chapter 1: INTRODUCTION

1.1. Background

1.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

1.1.2. Impairment Listing

The subjects of this TMDL study are eight impaired stream segments in two neighboring watersheds: four segments on Little Otter River; one segment each in Johns Creek and Wells Creek, both tributary to Little Otter River; and two segments on Buffalo Creek. These impaired segments are located within the Roanoke River Basin within Bedford City and Bedford and Campbell Counties in the Commonwealth of Virginia, Figure 1-1.

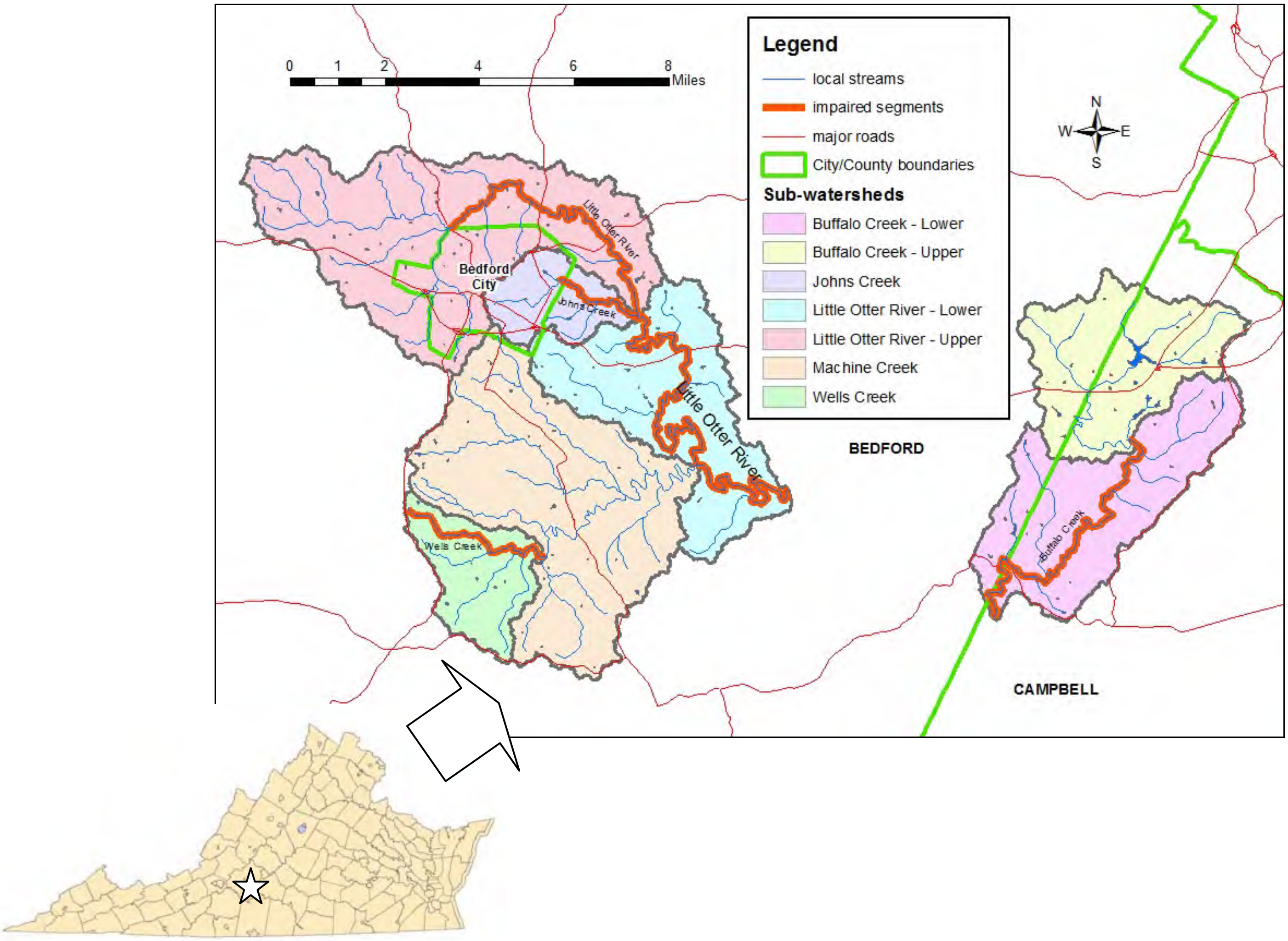


Figure 1-1. Location of Impaired Segments and Watersheds

Little Otter River

Little Otter River receives flow from both the Johns Creek and Wells Creek tributaries. The Little Otter Creek stream segment above the confluence with Johns Creek is referred to in this report as the Upper Little Otter River, and the Little Otter River stream segment between the confluence with Johns Creek and its downstream confluence with Big Otter River is referred to as Lower Little Otter Creek. Wells Creek is tributary to Machine Creek, which is tributary to the Lower Little Otter River.

The Upper Little Otter River was originally listed as impaired due to water quality violations of the general aquatic life (benthic) standard in the 2002 Virginia

303(d) Report (VADEQ, 2002). This impairment was based on biological monitoring at station 4ALOR014.75 and extended 5.71 miles upstream from its confluence with Johns Creek. In 2008, an additional 1.58 miles of stream was listed as impaired, extending upstream from the previous impairment for a total of 7.29 miles to its headwaters. In 2010, an impairment on the entire Lower Little Otter Creek (14.33 miles) was added based on the monitoring at stations 4ALOR012.20, 4ALOR008.64, and 4ALOR007.20, for a total combined impaired length on the Little Otter River of 21.62 miles. These impairments comprise DEQ's Cause Group Code L26R-01-BEN and consist of 4 impaired segments (VAW-L26R_LOR01A00, LOR02A00, LOR03A00, and LOR04A00). The Upper Little Otter River shows habitat impacts from sediment deposition in stream, eroded stream banks, and removal of vegetation in the riparian zone. The Lower Little Otter River shows similar habitat impacts with stream substrates embedded with fine sediments and eroding stream banks.

Johns Creek was originally listed with a benthic impairment in 2002 based on monitoring at station 4AJHN000.01. Johns Creek was listed for its entire length of 2.13 miles, from its headwaters to its confluence with Little Otter River. This impairment is listed as DEQ's Cause Group Code L26R-02-BEN and consists of just one impaired segment, VAW-L26R_JHN01A00. The stream is affected by urban and agricultural NPS pollution and flashy flows, which contribute to the erosion of its stream banks.

Wells Creek was listed initially with a benthic impairment in 2008 based on monitoring at station 4AWEL000.59. Wells Creek was listed for its entire length 3.78 miles, from its headwaters to its confluence with Machine Creek. This impairment is listed as DEQ's Cause Group Code L26R-03-BEN and consists of just one impaired segment, VAW-L26R_WEL01A02. The stream is affected by narrow riparian buffer zones and stream bank erosion, which contributes to deposition of fine sediment in the stream.

Buffalo Creek

Buffalo Creek was originally listed as impaired due to water quality violations of the general aquatic life (benthic) standard in the 2008 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report (VADEQ, 2008).

The Virginia Department of Environmental Quality (DEQ) has identified this impairment as Cause Group Code L27R-02-BEN, and delineated the benthic impairment as 8.09 miles on Buffalo Creek (stream segments VAC-L27R_BWA01A00 and VAC-L27R_BWA02A02). The Buffalo Creek impaired segment begins at an unnamed tributary at the Route 811 crossing in Campbell County to its confluence with the Big Otter River.

The DEQ 2008 Fact Sheets for Category 5 Waters (VADEQ, 2008) state that Buffalo Creek is impaired based on assessments at biological station 4ABWA008.53. The source of impairment is described as related to the surrounding residential land uses with "increasing sedimentation and flashy flows causing erosion and nutrient enrichment."

1.1.3. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to a violation of the benthic standard. A violation of this standard is assessed on the basis of measurements of the in-stream benthic macro-invertebrate community. Water bodies having a benthic impairment are not fully supportive of the aquatic life designated use for Virginia's waters.

1.2. Designated Uses and Applicable Water Quality Standards

1.2.1. Designation of Uses (9 VAC 25-260-10)

> "A. All state waters are designated for the following uses: recreational uses (e.g. swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)." SWCB, 2010.

1.2.2. General Standard (9 VAC 25-260-20)

The general standard for a water body in Virginia is stated as follows:

> "A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.
>
> Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled." SWCB, 2010.

The biological monitoring program in Virginia that is used to evaluate compliance with the above standard is administered by the Virginia Department of Environmental Quality (DEQ). Evaluations of monitoring data from this program focus on the benthic (bottom-dwelling) macro (large enough to see) invertebrates (insects, mollusks, crustaceans, and annelid worms) and are used to determine whether or not a stream segment has a benthic impairment. Changes in water quality generally result in alterations to the quantity and diversity of the benthic organisms that live in streams and other water bodies. Besides being the major intermediate constituent of the aquatic food chain, benthic macro-invertebrates are "living recorders" of past and present water quality conditions. This is due to their relative immobility and their variable resistance to the diverse contaminants that are introduced into streams. The community structure of these organisms provides the basis for the biological analysis of water quality. Both qualitative and semi-quantitative biological monitoring have been conducted by DEQ since the early 1970's. The U.S. Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocol (RBP) II was employed beginning in the fall of 1990 to utilize standardized and repeatable assessment methodology (Barbour et al., 1999). For any single sample, the RBP II produces water quality ratings of "non-impaired," "slightly impaired," "moderately impaired," or "severely impaired." In Virginia, benthic samples are typically collected and analyzed twice a year in the spring and in the fall.

The RBP II procedure evaluates the benthic macro-invertebrate community by comparing ambient monitoring "network" stations to "reference" sites. A reference site is one that has been determined to be representative of a natural, non-impaired water body. The RBP II evaluation also accounts for the natural variation noted in streams in different eco-regions. One additional product of the RBP II evaluation is a habitat assessment. This is a stand-alone assessment that describes bank condition and other stream and riparian corridor characteristics and serves as a measure of habitat suitability for the benthic community.

Beginning in 2006, DEQ modified their bioassessment procedures. While the RBP II protocols were still followed for individual metrics, a new index, the Virginia Stream Condition Index (VSCI), was developed based on comparison of observed data to a set of reference conditions, rather than with data from a reference station. The new index was also calculated for all previous samples in order to better assess trends over time.

Determination of the degree of support for the aquatic life designated use is based on biological monitoring data and the best professional judgment of the regional biologist, relying primarily on the most recent data collected during the current 5-year assessment period. In Virginia, any stream segment with a benthic score less than the impairment threshold is placed on the state's 303(d) list of impaired streams (VADEQ, 2012). In Virginia, any stream segment with an overall rating of "moderately impaired" or "severely impaired" is placed on the state's 303(d) list of impaired streams (VADEQ, 2002).

Chapter 2: WATERSHED CHARACTERIZATION

2.1. Water Resources

The Little Otter River watershed is part of the Roanoke River basin and comprises state hydrologic unit L26 (National Watershed Boundary Dataset watersheds RU53 and RU54). The Little Otter River watershed contains the City of Bedford, Virginia, is intersected by US Route 460 and Virginia Route 43, and lies entirely within Bedford County. The Little Otter River watershed is 43,914 acres in size. The main land use category in the watershed is hay and pasture, which comprises approximately 48% of the watershed, followed by 36% forest, 15% residential or developed land uses, and a very minor 1% in cropland. The Upper Little Otter River flows east southeast to its confluence with Johns Creek, which is the beginning of the Lower Little Otter River. Wells Creek flows east and confluences with Machine Creek, which continues its path in an eastern direction until it flows into the Lower Little Otter River. At that point the Lower Little Otter River flows east until it discharges into the Big Otter River. The Big Otter River is a tributary of the Roanoke River, which flows into the Albemarle Sound.

The Buffalo Creek watershed is part of the Roanoke River basin and comprises part of state hydrologic unit L27 (National Watershed Boundary Dataset RU56). Buffalo Creek is located southwest of Lynchburg on US Route 460 and US Route 221 in both Bedford and Campbell counties. The Buffalo Creek watershed is 15,808 acres in size. The main land use category in the watershed is forest, which comprises approximately 51% of the watershed, followed by 28% pasture, 21% residential or developed land uses, and a very minor 0.4% in cropland. Buffalo Creek flows south southwest, with part of its flow intercepted by Timber Lake above the impaired segment, and discharges into the Big Otter River. The Big Otter River is a tributary of the Roanoke River Basin, which flows into the Albemarle Sound.

2.2. Eco-region

Both of the Little Otter River and Buffalo Creek watersheds are located entirely within the Northern Inner Piedmont (45e) sub-division of the Piedmont (45) ecoregion. Ecoregion 45e is a dissected upland composed of hills, irregular plains, and isolated ridges and mountains. General elevations become higher towards the western boundary and to the south the Roanoke River where the land rises to become a broad, hilly upland. Ecoregion 45e is characteristically underlain by highly deformed and deeply weathered Cambrian and Proterozoic feldspathic gneiss, schist, and melange. Streams have silt, sand, gravel, and rubble bottoms materials and bedrock is only occasionally exposed. Differences in stream gradient considerably affect fish habitat in the Piedmont. Loblolly – shortleaf pine forests are common (USEPA, 2002).

2.3. Soils and Geology

The Little Otter River watershed is comprised of a diversity of soils with its dominant soil, Cecil fine sandy loam, comprising 34.6% of the watershed. The next two most abundant soil types are Madison sandy clay loam and Hayesville loam at 23.8% and 14.3%, respectively. The Cecil series (fine, kaolinitic, thermic Typic Kanhapludults) consists of very deep, well drained moderately permeable soils on ridges and side slopes of the Piedmont uplands. They are deep to saprolite and very deep to bedrock. They formed in residuum weathered from felsic, igneous and high-grade metamorphic rocks of the Piedmont uplands. The Madison series (fine, kaolinitic, thermic Typic Kanhapludults) consists of well drained, moderately permeable soils that formed in residuum weathered from felsic or intermediate, high-grade metamorphic or igneous rocks high in mica content. They are very deep to bedrock and moderately deep to saprolite. They are on gently sloping to steep uplands in the Piedmont. The Hayesville series (fine, kaolinitic, mesic Typic Kanhapludults) consists of very deep, well drained soils on gently sloping to very steep ridges and side slopes of the Southern Appalachian Mountains. They most commonly formed in residuum weathered from igneous and high-grade metamorphic rocks such as granite, granodiorite, mica gneiss and schist; but in some places formed from thickly-bedded metagraywacke and metasandstone. On steeper slopes the upper part of some pedons may have some colluvial influence (USDA-NRCS, 2012).

The Buffalo Creek watershed is comprised of a diversity of soils with its dominant soil also being Cecil fine sandy loam, which comprising 28.2% of the watershed. The next two most abundant soil types are Cullen loam and Tatum loam at 11.4% and 11.3%, respectively. The Cecil series is described above for the Little Otter River. The Cullen series (very-fine, kaolinitic, thermic Typic Hapludults) are very deep and well drained with moderate permeability. They formed in residuum from mixed mafic and felsic crystalline rocks. These soils are on upland ridgetops and side slopes of the Piedmont Plateau. The Tatum series (fine, mixed, semiactive, thermic Typic Hapludults) consists of deep, well-drained, moderately permeable soils. They formed in residuum weathered from fine-grained metamorphic rocks (USDA-NRCS, 2012).

2.4. Climate

Climate data for the Little Otter River watershed was based on meteorological observations made by the Bedford National Climatic Data Center station (440551) located within Bedford City, Virginia and on the upstream boundary of the Johns Creek and the Upper Little Otter River watersheds. Average annual precipitation at this station is 45.08 inches; while the average annual daily temperature is 56.1°F. The highest average daily temperature of 75.8°F occurs in August while the lowest average daily temperature of 35.7°F occurs in January, as obtained from the 1981-2010 climate normals (NCDC-NOAA, 2012).

Climate data for the Buffalo Creek watershed was based on meteorological observations made by the Lynchburg #2 National Climatic Data Center station (445120) located within Lynchburg City, Virginia approximately 5.0 miles north northeast of Timber Lake and approximately 11.4 miles north northeast from the Buffalo Creek outlet into Big Otter River. Average annual precipitation at this station is 41.48 inches; while the average annual daily temperature is 54.7°F. The highest average daily temperature of 84.4°F occurs in July while the lowest average daily temperature of 23.6°F occurs in January, as obtained from the 1981-2010 climate normals (NCDC-NOAA, 2012).

2.5. Land Use

Land use categories for the Little Otter River and Buffalo Creek watersheds were derived from the 2009 cropland data layer developed by the USDA National Agricultural Statistics Service (NASS, 2009). The NASS data are available online and were developed from USDA National Resources Inventory data in agricultural areas and supplemented with 2006 National Land Classification Data (NLCD) in non-agricultural areas. The Little Otter River watershed is 43,913.9 acres in size. The main land use category in the watershed is pasture/hay (47.5% of the watershed), followed by forest (36.5%), 14.9% developed, and the remainder in cropland (1%). The distribution of land use acreages in the watershed is given in Table 2-1, and shown in Figure 2-1.

Table 2-1. NASS Land Use Summary in Little Otter River Watersheds (acres)

NASS Land Use Categories	Johns Creek	Upper Little Otter River	Wells Creek	Lower Little Otter River	LOR Total
Corn	11.62	9.30	3.10	241.00	265.02
Sorghum	0.77	2.32	0.00	3.10	6.20
Soybeans	0.00	0.77	0.00	2.32	3.10
Barley	0.00	1.55	0.77	13.17	15.50
Winter Wheat	2.32	0.77	0.00	78.27	81.37
W. Wht./Soy. Dbl. Crop	0.00	0.00	0.00	1.55	1.55
Rye	0.00	3.10	3.10	14.72	20.92
Oats	0.00	11.62	0.00	0.00	11.62
Millet	0.00	0.00	0.00	0.77	0.77
Alfalfa	0.00	17.05	0.77	3.10	20.92
Other Hays	457.19	6,550.28	2,411.51	11,378.71	20,797.69
Pasture/Grass	8.52	13.17	3.87	24.02	49.59
NLCD - Open Water	0.77	13.95	6.20	14.72	35.65
NLCD - Developed/Open Space	425.42	1,674.57	171.25	1,369.26	3,640.51
NLCD - Developed/Low Intensity	563.36	1,266.20	36.42	556.38	2,422.35
NLCD - Developed/Medium Intensit	171.25	182.10	0.00	27.90	381.25
NLCD - Developed/High Intensity	63.54	39.52	0.00	4.65	107.71
NLCD - Barren	4.65	0.77	0.00	0.00	5.42
NLCD - Deciduous Forest	845.42	4,172.87	713.69	7,801.75	13,533.73
NLCD - Evergreen Forest	99.96	574.98	149.56	1,277.04	2,101.54
NLCD - Mixed Forest	24.80	120.89	18.60	220.07	384.35
NLCD - Shrubland	0.00	0.00	0.00	0.00	0.00
NLCD - Grassland Herbaceous	0.00	0.77	0.00	4.65	5.42
NLCD - Herbaceous Wetlands	0.77	0.00	0.00	0.00	0.77
Strawberries	0.00	0.00	0.00	2.32	2.32
Dbl. Crop WinWht/Corn	0.00	1.55	0.00	6.20	7.75
Dbl. Crop Barley/Corn	0.77	0.00	0.00	10.07	10.85
Total Area (acres)	**2,681.17**	**14,658.11**	**3,518.85**	**23,055.77**	**43,913.90**

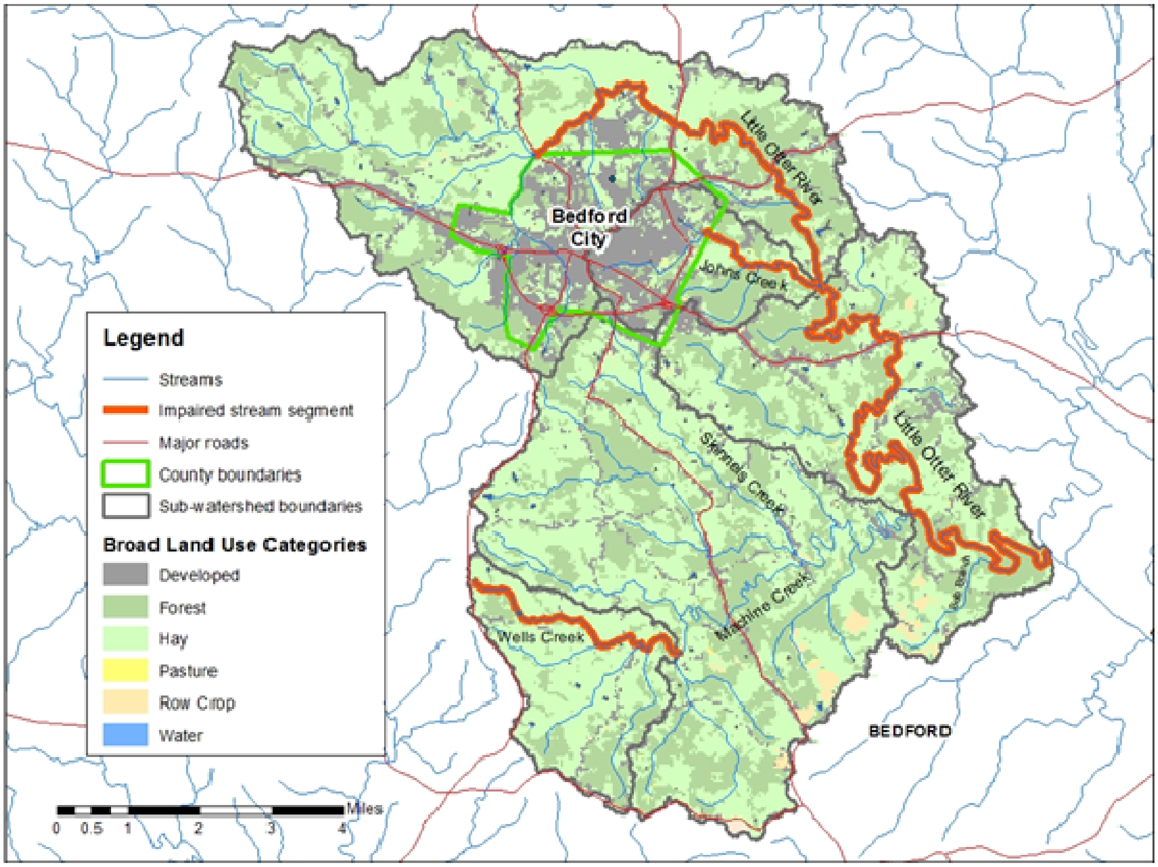


Figure 2-1. NASS Generalized Land Use in Little Otter River Watersheds

The Buffalo Creek watershed is 15,808.1 acres in size. The main land use categories in the watershed are forest (50.6% of the watershed), pasture/hay (27.7%), and residential or developed (20.7%) land uses. The remaining less than 1% is in cropland. The distribution of land use acreages in the watershed is given in Table 2-1, and shown in Figure 2-1.

Table 2-2. NASS Land Use Summary in Buffalo Creek Watersheds (acres)

NASS Land Use Categories	Lower Buffalo Creek	Upper Buffalo Creek	BWA Total
Corn	6.97	43.39	50.37
Sorghum	0.00	0.00	0.00
Soybeans	0.00	3.10	3.10
Barley	0.00	0.77	0.77
Winter Wheat	0.00	3.87	3.87
W. Wht./Soy. Dbl. Crop	0.00	4.65	4.65
Rye	0.00	0.00	0.00
Oats	0.00	0.00	0.00
Millet	0.00	0.00	0.00
Alfalfa	0.00	15.50	15.50
Other Hays	1,547.49	1,664.50	3,211.98
Pasture/Grass	503.69	309.96	813.65
NLCD - Open Water	8.52	88.34	96.86
NLCD - Developed/Open Space	547.86	1,528.11	2,075.97
NLCD - Developed/Low Intensity	101.51	877.19	978.71
NLCD - Developed/Medium Intensit	3.10	179.78	182.88
NLCD - Developed/High Intensity	1.55	33.32	34.87
NLCD - Barren	0.77	0.00	0.77
NLCD - Deciduous Forest	5,065.56	2,254.98	7,320.53
NLCD - Evergreen Forest	484.32	144.91	629.22
NLCD - Mixed Forest	24.80	17.05	41.84
NLCD - Shrubland	63.54	9.30	72.84
NLCD - Grassland Herbaceous	248.74	20.92	269.67
NLCD - Herbaceous Wetlands	0.00	0.00	0.00
Strawberries	0.00	0.00	0.00
Dbl. Crop WinWht/Corn	0.00	0.00	0.00
Dbl. Crop Barley/Corn	0.00	0.00	0.00
Total Area (acres)	**8,608.43**	**7,199.65**	**15,808.07**

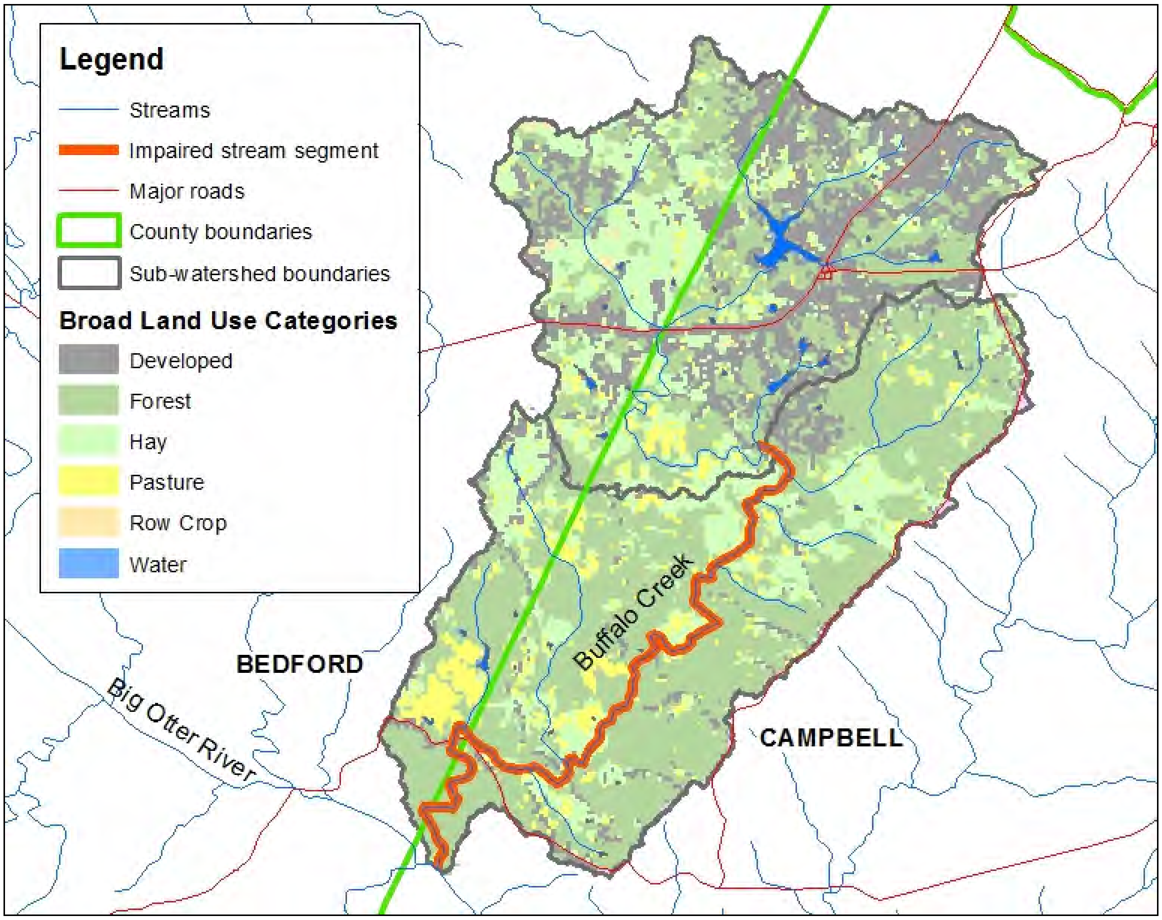


Figure 2-2. NASS Generalized Land Use in Buffalo Creek Watersheds

2.6. Future Land Use

Future land use was assessed from a combination of the Bedford County Future Land Use spatial data layer associated with the Bedford County 2025 Comprehensive Plan, the City of Bedford 2012 Comprehensive Plan (no map), the Campbell County on-line GIS data layers for tax parcels and zoning, and the census data for the area in both 2000 and 2010. The future land use scenario was constructed by reducing all agriculture and forestry land uses by an assigned future ag reduction percentage and redistributing the changed acreage on proportional basis to all developed land use categories.

2.7. Biological Monitoring Data – Benthic Macro-invertebrates

Biological monitoring consisted of sampling the benthic macro-invertebrate community along with corresponding habitat assessments. The data for the bioassessments in Little Otter River and Buffalo Creek were based on DEQ biological monitoring at one or more DEQ monitoring sites in each watershed. The locations of the DEQ biological and ambient monitoring stations in the Little Otter River and Buffalo Creek watersheds are shown in Figure 2-3. Monitoring station 4ABWA008.57 was moved to mile marker 8.53 in 2010.

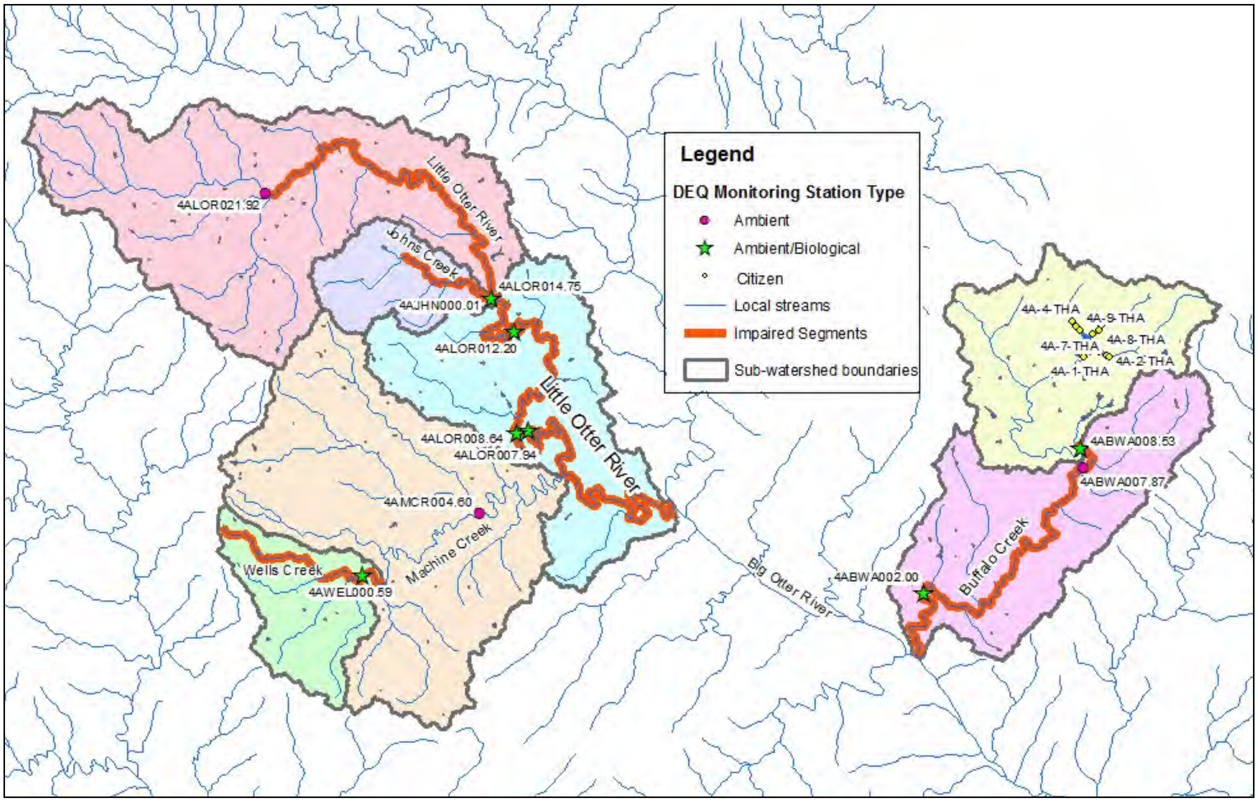


Figure 2-3. Locations of DEQ Monitoring Stations in the Little Otter River and Buffalo Creek Watersheds

Biological samples were collected from the best available habitat using riffle or multi-habitat methods. The samples were then preserved and subsorted, and then the organisms were identified to the family and/or genus taxonomic level. A full listing of the benthic macro-invertebrate taxa inventory or distribution within each biological sample is given for four Little Otter River impairment sub-watersheds in Table 2-3 through Table 2-9, and for Buffalo Creek in Table 2-11.

In 2006, DEQ upgraded its biomonitoring and biological assessment methods to those currently recommended by USEPA Region 3 for the mid-Atlantic region. As part of this effort, a study was performed to assist the agency in moving from a paired-network/reference site approach based on the RBP II to a regional reference condition approach, and has led to the development of the Virginia Stream Condition Index (VSCI) for Virginia's non-coastal areas (Tetra Tech, 2003). This multi-metric index is based on 8 biomonitoring metrics, with a scoring range of 0-100, that include some different metrics than those used previously in the RBP II, but are based on the same taxa inventory. A maximum score of 100 represents the best benthic community sites. The current criteria define "non-impaired" sites as those with a VSCI of 60 or above, and "impaired" sites as those with a score below 60 (VADEQ, 2006).

Upper Little Otter River

The biological summaries for the Upper Little Otter River are in Table 2-3, Table 2-4, and Figure 2-4, including a trend line for the single station. The dominant family of benthic macro-invertebrates is the pollution-tolerant Hydropsychidae (net-spinner caddisflies) combined with second dominant family typically being more pollution-sensitive, indicative of better water quality. Individual VSCI metric scores are on a scale of 0-100, with 100 being the best possible score. The primary biological effects are identified as those metrics scoring in the lowest 20th percentile. The primary biological effects in the Upper Little Otter River, indicative of its relatively minor impairment, are the occasional low scores for the scraper functional group and for the sensitive members of the Plecoptera (stoneflies) and Tricoptera (case maker caddisflies) families.

Table 2-3. Taxa Inventory by Sample Date in the Upper Little Otter River (LOR)

Family	Tolerance Value	4ALOR014.75												
		11/02/94	04/27/95	12/06/95	06/10/97	04/07/99	10/27/99	05/15/00	10/03/06	05/22/08	10/16/08	06/07/11	11/09/11	06/06/12
Capniidae	1	7					4		3		13		51	
Chloroperlidae	1												2	
Gomphidae	1					2	2	1		1	1			
Perlidae	1	1	1					5		15		3		1
Athericidae	2					2								
Isonychiidae	2	30	5	2	4	9	27	30	7	6	1		2	6
Perlodidae	2				7					2	3			
Taeniopterygidae	2						1	5			5		11	
Philopotamidae	3							6		6	2	49		
Tipulidae	3	2	2		2		2	1	1	1	3	1		
Baetidae	4	19	8		4		2		13			11	2	21
Elmidae	4	2	1			2	10	1	25	16	11	6	5	2
Ephemerellidae	4		16	18	6	32	1	5		7	3	2	2	
Heptageniidae	4	12	11	6		4	17	5	20		15	4	5	6
Leptohyphidae	4							2						
Cambaridae	5	3									1			
Corydalidae	5	2	6	2	6	9	3	2	2			2		2
Ptilodactylidae	5						2							
Chironomidae (A)	6	1	2	2	2	16	17	6	9	22	14		9	26
Empididae	6													2
Hydropsychidae	6	37	77	59	77	38	18	27	41	36	33	27	17	29
Simuliidae	6	2	5			3	1	11	2	2	1	4	2	15
Tabanidae	6					3								
Oligochaeta (unknown)	6										2			
Siphlonuridae	7				5									
Corbiculidae	8		2		5	3	1	1	1					
Lumbriculidae	8			1									1	
Plecoptera (unknown)	(blank)										4			
No. of families		**13**	**12**	**9**	**10**	**12**	**16**	**15**	**12**	**13**	**18**	**11**	**20**	**17**
Abundance		**119**	**136**	**92**	**118**	**123**	**109**	**108**	**125**	**116**	**114**	**110**	**110**	**110**
Additional Benthic Metrics														
Scraper/Filterer-Collector		16.9%	10.4%	8.4%	0.0%	5.9%	39.7%	6.8%	63.0%	20.0%	46.4%	10.6%	28.6%	8.2%
%Filterer-Collector		74.8%	84.6%	90.2%	87.3%	82.1%	62.4%	81.5%	58.4%	69.0%	49.1%	85.5%	31.8%	88.2%
%Haptobenthos		47.9%	86.0%	92.4%	81.4%	71.5%	47.7%	57.4%	72.0%	73.3%	59.6%	88.2%	30.0%	50.0%
%Shredder		10.1%	1.5%	0.0%	1.7%	0.0%	8.3%	5.6%	3.2%	1.7%	19.3%	0.9%	56.4%	0.0%

- Dominant 2 families in each sample.

11 additional taxa were identified with only 1 organism in 1 of the samples.

Table 2-4. Biological Index (VSCI) Scores for Upper Little Otter River (LOR)

StationID	4ALOR014.75												
CollDate	11/02/94	04/27/95	12/06/95	06/10/97	04/07/99	10/27/99	05/15/00	10/03/06	05/22/08	10/16/08	06/07/11	11/09/11	06/06/12
VSCI Metric Values													
Total Taxa	13	12	9	10	12	16	15	12	13	17	13	11	10
EPT Taxa	6	6	4	6	4	8	8	5	7	8	9	7	5
% Ephemeroptera	51.3	29.4	28.3	16.1	36.6	44.0	38.9	32.0	11.2	16.7	16.4	10.0	30.0
%PT - Hydropsychidae	6.7	0.7		5.9		4.6	14.8	2.4	20.7	23.7	47.3	59.1	0.9
%Scrapers	12.6	8.8	7.6	0.0	4.9	24.8	5.6	36.8	13.8	22.8	9.1	4.5	7.3
%Chironomidae	0.8	1.5	2.2	1.7	13.0	15.6	5.6	7.2	19.0	12.3	0.0	8.2	23.6
%2 Dominant	56.3	68.4	83.7	71.2	56.9	41.3	52.8	52.8	50.0	42.1	61.8	68.2	50.0
MFBI	4.0	5.2	5.4	5.5	4.9	4.0	4.0	4.7	4.4	4.4	2.9	4.9	5.2
VSCI Metric Scores													
Richness Score	59.1	54.5	40.9	45.5	54.5	72.7	68.2	54.5	59.1	77.3	59.1	50.0	45.5
EPT Score	54.5	54.5	36.4	54.5	36.4	72.7	72.7	45.5	63.6	72.7	81.8	63.6	45.5
%Ephemeroptera Score	83.6	48.0	46.1	26.3	59.7	71.8	63.4	52.2	18.3	27.2	26.7	16.3	48.9
%PT-H Score	18.9	2.1	0.0	16.7	0.0	12.9	41.6	6.7	58.1	66.5	100.0	100.0	2.6
%Scraper Score	24.4	17.1	14.7	0.0	9.5	48.0	10.8	71.3	26.7	44.2	17.6	8.8	14.1
%Chironomidae Score	99.2	98.5	97.8	98.3	87.0	84.4	94.4	92.8	81.0	87.7	100.0	91.8	76.4
%2Dominant Score	63.1	45.7	23.6	41.6	62.3	84.8	68.2	68.2	72.3	83.7	55.2	46.0	72.3
%MFBI Score	88.1	70.2	67.5	66.4	74.7	87.7	88.4	78.1	82.0	82.8	100.0	74.6	70.7
VSCI	61	49	41	44	48	67	63	59	58	68	61	65	47
VSCI Rating	Good	Stressed	Severe Stress	Stressed	Stressed	Good	Good	Stressed	Stressed	Good	Good	Good	Stressed

- Primary biological effects.
VSCI: Non-impaired ≥ 60; impaired < 60.

VSCI = Virginia Stream Condition Index
EPT = Ephemeroptera, Plecoptera, and Tricoptera
MFBI = Modified Family Biotic Index

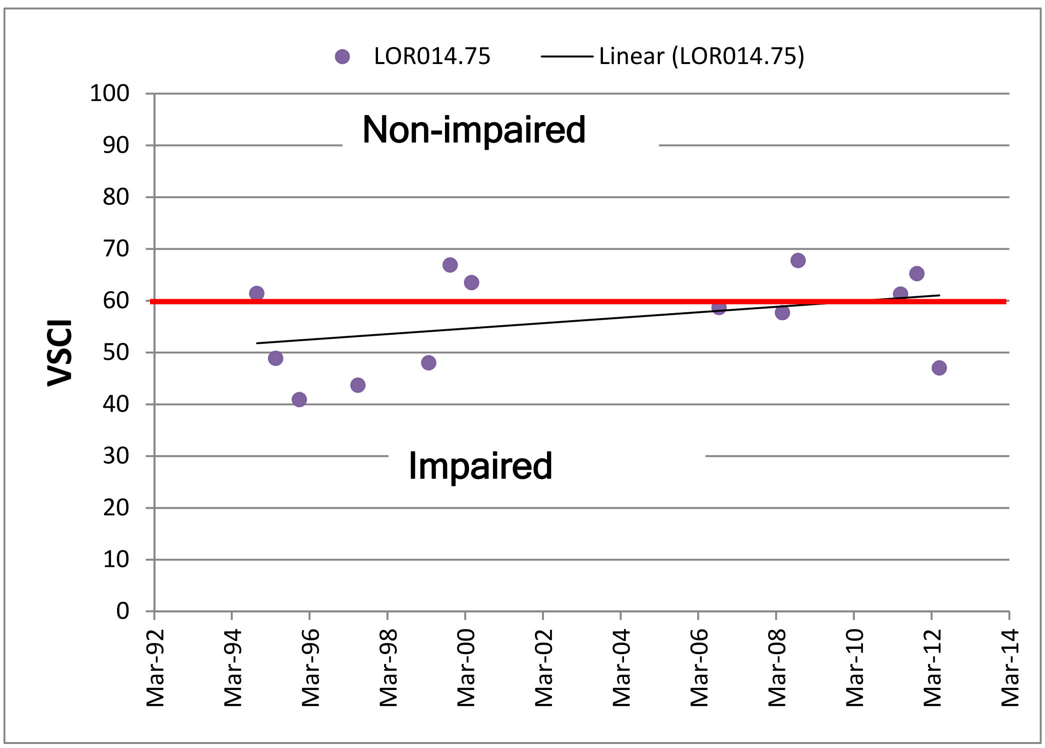


Figure 2-4. VSCI Trend for Upper Little Otter River (LOR)

Johns Creek

The biological summaries for Johns Creek are in Table 2-5, Table 2-6, and Figure 2-5, including a trend line for the single station. The dominant family of benthic macro-invertebrates are the pollutant-tolerant Chironomidae and Hydropsychidae, with occasional dominance by one of the more pollutant-sensitive families. Johns Creek is consistently impaired, but has shown gradual improvement. Individual VSCI metric scores are on a scale of 0-100, with 100 being the best possible score. The primary biological effects are identified as those metrics scoring in the lowest 20th percentile. The primary biological effects in Johns Creek, which parallel its gradual improvement over time, are the scores for the scraper functional group and for the sensitive members of the Plecoptera and Tricoptera families.

Table 2-5. Taxa Inventory by Sample Date in Johns Creek (JHN)

Family	Tolerance Value	4AJHN000.01								
		10/17/97	04/07/99	05/15/00	10/03/06	05/22/08	10/16/08	06/07/11	11/09/11	06/06/12
Capniidae	1				2		2		17	
Isonychiidae	2	1	1			2	9	7	5	1
Taeniopterygidae	2								10	
Philopotamidae	3				1		1		1	
Tipulidae	3	4		1		2	2	2	3	1
Baetidae	4			2	18	8	2	42	1	42
Caenidae	4						1		1	
Elmidae	4			1	3	8	3	1	5	
Ephemerellidae	4		3	1		5	1			1
Heptageniidae	4	3	2	3	4	1	4		3	
Corydalidae	5	1	3		1					2
Ancylidae	6						4		2	
Chironomidae (A)	6	2	12	14	7	36	23	10	46	19
Hydropsychidae	6	75	20	23	83	37	47	40	7	35
Simuliidae	6	1	1	44	4	13	2	8	7	7
Tabanidae	6		2		1					
Lumbriculidae	8	1							1	
Naididae	8					3				
No. of families		**8**	**8**	**9**	**10**	**10**	**18**	**7**	**18**	**14**
Abundance		**88**	**44**	**90**	**124**	**115**	**106**	**110**	**110**	**110**
Additional Benthic Metrics										
Scraper/Filterer-Collector		3.8%	5.4%	4.8%	6.2%	8.7%	13.8%	0.9%	15.9%	0.0%
%Filterer-Collector		90.9%	84.1%	93.3%	91.1%	90.4%	82.1%	97.3%	62.7%	95.5%
%Haptobenthos		90.9%	65.9%	80.0%	77.4%	55.7%	58.5%	44.5%	22.7%	40.9%
%Shredder		4.5%	0.0%	1.1%	1.6%	1.7%	3.8%	1.8%	27.3%	0.9%

- Dominant 2 species in each sample.

9 additional taxa were identified with only 1 organism in all samples.

Table 2-6. Biological Index (VSCI) Scores for Johns Creek (JHN)

StationID	4AJHN000.01								
CollDate	10/17/97	04/07/99	05/15/00	10/03/06	05/22/08	10/16/08	06/07/11	11/09/11	06/06/12
VSCI Metric Values									
Total Taxa	8	8	9	10	10	18	7	15	10
EPT Taxa	3	4	4	5	5	9	3	8	5
% Ephemeroptera	4.5	13.6	6.7	17.7	13.9	17.0	44.5	9.1	40.0
%PT - Hydropsychidae				2.4		2.8		25.5	0.9
%Scrapers	3.4	4.5	4.4	5.6	7.8	11.3	0.9	10.0	0.0
%Chironomidae	2.3	27.3	15.6	5.6	31.3	21.7	9.1	41.8	17.3
%2 Dominant	89.8	72.7	74.4	81.5	63.5	66.0	74.5	57.3	70.0
MFBI	5.8	5.6	5.8	5.5	5.5	5.2	4.9	4.4	5.1
VSCI Metric Scores									
Richness Score	36.4	36.4	40.9	45.5	45.5	81.8	31.8	68.2	45.5
EPT Score	27.3	36.4	36.4	45.5	45.5	81.8	27.3	72.7	45.5
%Ephemeroptera Score	7.4	22.2	10.9	28.9	22.7	27.7	72.7	14.8	65.3
%PT-H Score	0.0	0.0	0.0	6.8	0.0	7.9	0.0	71.5	2.6
%Scraper Score	6.6	8.8	8.6	10.9	15.2	21.9	1.8	19.4	0.0
%Chironomidae Score	97.7	72.7	84.4	94.4	68.7	78.3	90.9	58.2	82.7
%2Dominant Score	14.8	39.4	36.9	26.8	52.8	49.1	36.8	61.7	43.4
%MFBI Score	62.3	64.5	61.8	66.4	65.5	70.8	74.9	82.1	72.5
VSCI	**32**	**35**	**35**	**41**	**39**	**52**	**42**	**56**	**45**
VSCI Rating	**Severe Stress**	**Severe Stress**	**Severe Stress**	**Severe Stress**	**Severe Stress**	**Stressed**	**Stressed**	**Stressed**	**Stressed**

- Primary biological effects.
VSCI: Non-impaired ≥ 60; impaired < 60.

VSCI = Virginia Stream Condition Index
EPT = Ephemeroptera, Plecoptera, and Tricoptera
MFBI = Modified Family Biotic Index

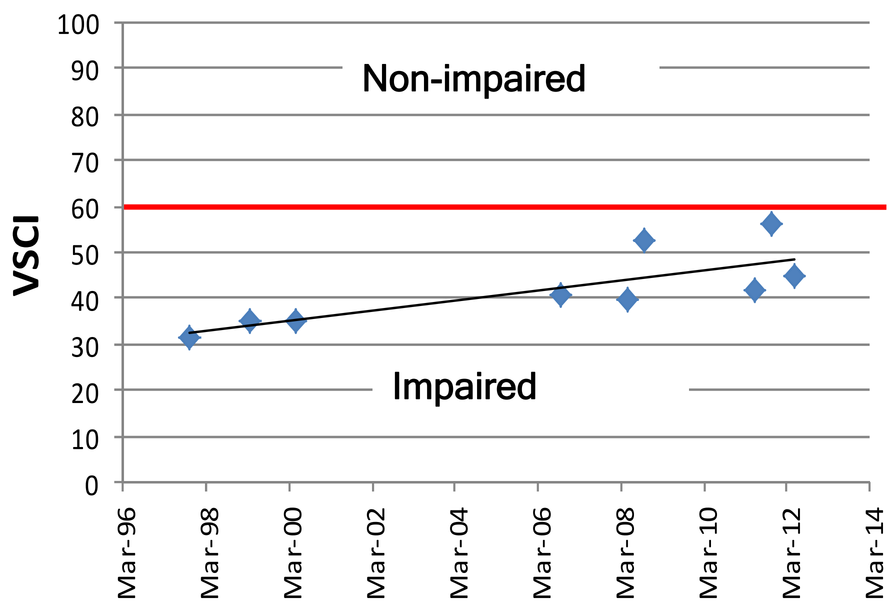


Figure 2-5. VSCI Trend for Johns Creek (JHN)

Wells Creek

The biological summaries for Wells Creek are in Table 2-7, Table 2-8, and Figure 2-6. The dominant family of benthic macro-invertebrates is the pollutant-tolerant Chironomidae and occasionally, the slightly more sensitive Heptageniidae (mayflies). Individual VSCI metric scores are on a scale of 0-100, with 100 being the best possible score. The primary biological effects are identified as those metrics scoring in the lowest 20th percentile. The primary biological effects in Wells Creek have been the occasional low scores for the scraper functional group and for the sensitive members of the Plecoptera and Tricoptera families. All spring samples have shown impairment, while all fall samples rated as "non-impaired".

Table 2-7. Taxa Inventory by Sample Date in Wells Creek (WEL)

Family	Tolerance Value	4AWEL000.59		4AWEL001.14		
		05/25/05	09/19/05	06/13/11	11/15/11	05/07/12
Capniidae	1				6	
Gomphidae	1		2	1	1	
Isonychiidae	2	2	1	1		2
Taeniopterygidae	2			1	6	
Philopotamidae	3		1			1
Tipulidae	3	13	5			3
Baetidae	4	15	6			6
Caenidae	4		2			
Elmidae	4	2	17	31	4	5
Ephemerellidae	4	2	1		2	
Heptageniidae	4	6	33	5	49	4
Cambaridae	5	1	1			
Corydalidae	5			6		
Chironomidae (A)	6	32	27	36	26	56
Hydropsychidae	6	20	60	27	11	13
Simuliidae	6	36		2	1	7
Oligochaeta (unknown)					2	11
Plecoptera (unknown)					1	1
No. of families		**11**	**15**	**9**	**13**	**14**
Abundance		**130**	**159**	**110**	**110**	**110**
Additional Benthic Metrics						
Scraper/Filterer-Collector		7.5%	51.5%	54.5%	129.3%	10.6%
%Filterer-Collector		82.3%	62.3%	60.0%	37.3%	77.3%
%Haptobenthos		50.8%	70.4%	64.5%	60.9%	27.3%
%Shredder		10.8%	4.4%	0.9%	10.9%	2.7%

- Dominant 2 species in each sample.

6 additional taxa were identified with only 1 organism in all samples.

Table 2-8. Biological Index (VSCI) Scores for Wells Creek (WEL)

StationID	4AWEL000.59		4AWEL001.14		
CollDate	05/25/05	09/19/05	06/13/11	11/15/11	05/07/12
VSCI Metric Values					
Total Taxa	11	15	9	12	12
EPT Taxa	6	9	4	6	6
% Ephemeroptera	19.2	27.7	5.5	46.4	10.9
%PT - Hydropsychidae	0.8	1.3	0.9	11.8	1.8
%Scrapers	6.2	32.1	32.7	48.2	8.2
%Chironomidae	24.6	17.0	32.7	23.6	50.9
%2 Dominant	52.3	58.5	60.9	68.2	62.7
MFBI	5.2	5.0	5.2	4.4	5.5
VSCI Metric Scores					
Richness Score	50.0	68.2	40.9	54.5	54.5
EPT Score	54.5	81.8	36.4	54.5	54.5
%Ephemeroptera Score	31.4	45.1	8.9	75.6	17.8
%PT-H Score	2.2	3.5	2.6	33.2	5.1
%Scraper Score	11.9	62.2	63.4	93.4	15.9
%Chironomidae Score	75.4	83.0	67.3	76.4	49.1
%2Dominant Score	68.9	60.0	56.5	46.0	53.9
%MFBI Score	70.5	73.2	71.0	81.8	66.3
VSCI	**46**	**59.6**	**43**	**64**	**40**
VSCI Rating	**Stressed**	**Stressed**	**Stressed**	**Good**	**Severe Stress**

- Primary biological effects.
VSCI = Virginia Stream Condition Index
VSCI: Non-impaired ≥ 60; impaired < 60.
EPT = Ephemeroptera, Plecoptera, and Tricoptera
MFBI = Modified Family Biotic Index

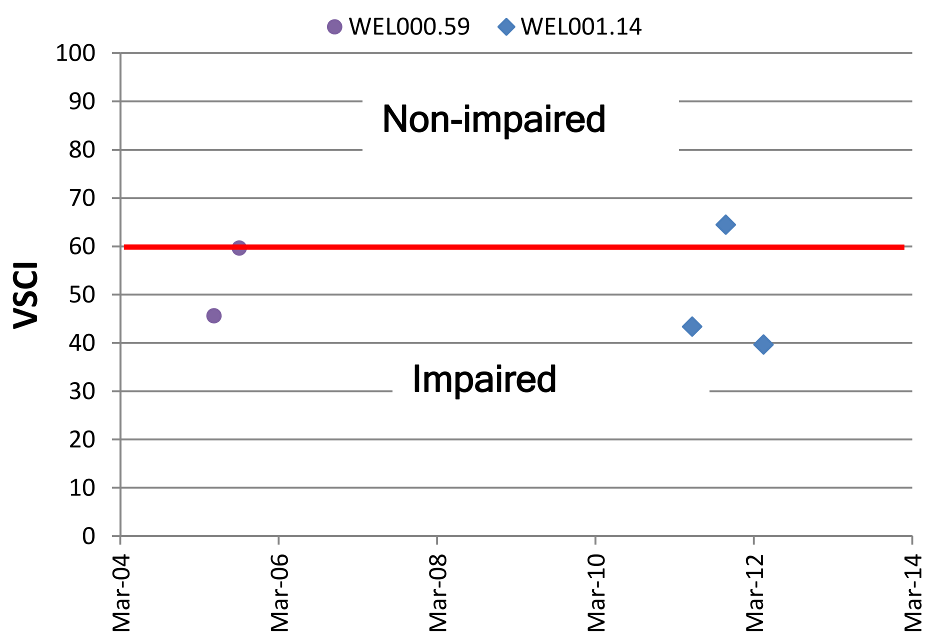


Figure 2-6. VSCI Scores for Wells Creek (WEL)

Lower Little Otter River

The biological summaries for the Lower Little Otter River are in Table 2-9, Table 2-10, and Figure 2-7, including a trend line for the upstream station. The dominant families of benthic macro-invertebrates are the pollution-tolerant Chironomidae (midges) and Hydropsychidae. Individual VSCI metric scores are on a scale of 0-100, with 100 being the best possible score. The primary biological effects are identified as those metrics scoring in the lowest 20th percentile. The primary biological effects in the Lower Little Otter River, indicative of its relatively minor impairment, are the occasional low scores for the scraper functional group and for the sensitive members of the Plecoptera and Tricoptera families.

Table 2-9. Taxa Inventory by Sample Date in the Lower Little Otter River (LOR)

Family	Tolerance Value	4ALOR007.20		4ALOR008.64	4ALOR012.20		4ALOR014.33										
		04/23/07	10/23/07	10/15/08	05/22/08	10/15/08	11/02/94	04/27/95	12/06/95	06/10/97	10/17/97	04/07/99	10/27/99	05/15/00	06/07/11	11/09/11	06/06/12
Rhyacophilidae	0		1							1							
Brachycentridae	1				3												
Capniidae	1		4				6						2			17	
Gomphidae	1				1	5						1				1	
Perlidae	1	3	1		3		1	2					1	3	3		
Isonychiidae	2	1	4	8	4		6			15			13	12	4	4	1
Nemouridae	2	1			1												
Perlodidae	2									4		1		6		4	
Taeniopterygidae	2		2	6							1			4		1	
Aeshnidae	3	1							2			1					
Tipulidae	3	2		4	3		1	1			8		5			1	
Baetidae	4	8		1		2	5	6		14					19	3	46
Caenidae	4				14												
Elmidae	4	3	6	3	5	30	2		2				1		3	4	3
Ephemerellidae	4	10			2			11	22	1		33		1	5	2	1
Ephemeridae	4					2											
Heptageniidae	4	13	18	24	3	1	5	15	1	1	6		10		2	9	2
Leptohyphidae	4							2									
Cambaridae	5		1										1	1	1		
Corduliidae	5					2											
Corydalidae	5									2	5	5	10	1	2		
Gyrinidae	5														2		
Hydracarina (unknown)	5					9											
Ancylidae	6		2	1	1		4										
Chironomidae (A)	6	43	6	30	31	15	2	41	4	8	13	23	27	13	30	47	29
Empididae	6	1														1	1
Gammaridae	6					2											
Hydropsychidae	6	19	61	15	26		70	59	56	25	46	30	6	25	37	13	20
Hydroptilidae	6		1	1													
Polycentropodidae	6					4											
Simuliidae	6	4		4			1			8		4		3	2		5
Tabanidae	6									2						1	
Oligochaeta (unknown)	6					2											
Planorbidae	7					19											
Siphlonuridae	7									12	1						
Asellidae	8				3	2										1	
Corbiculidae	8			2		4		1		1							
Lumbriculidae	8								4			1				1	
Naididae	8				8												
Physidae	8					8											
Chironomidae (B)	9											4					
Coenagrionidae	9					5			1								
No. of families		**13**	**12**	**12**	**19**	**18**	**11**	**9**	**9**	**13**	**7**	**10**	**11**	**11**	**16**	**20**	**14**
Abundance		**109**	**107**	**99**	**112**	**114**	**103**	**138**	**93**	**94**	**80**	**103**	**77**	**70**	**110**	**110**	**110**
Additional Benthic Metrics																	
Scraper/Filterer-Collector		18.8%	38.0%	48.3%	9.8%	170.6%	13.1%	12.5%	3.4%	1.2%	10.0%	0.0%	23.9%	0.0%	5.2%	18.3%	4.9%
%Filterer-Collector		78.0%	66.4%	60.6%	82.1%	29.8%	81.6%	87.0%	93.5%	89.4%	75.0%	92.2%	59.7%	78.6%	88.2%	64.5%	92.7%
%Haptobenthos		47.7%	84.1%	48.5%	39.3%	30.7%	80.6%	63.0%	87.1%	44.7%	71.3%	70.9%	36.4%	55.7%	49.1%	29.1%	29.1%
%Shredder		2.8%	6.5%	10.1%	4.5%	0.0%	6.8%	0.7%	0.0%	0.0%	11.3%	0.0%	10.4%	7.1%	0.9%	17.3%	0.9%

- Dominant 2 species in each sample.

11 additional taxa were identified with only 1 organism in all samples.

Table 2-10. Biological Index (VSCI) Scores for Lower Little Otter River (LOR)

StationID	4ALOR007.20		4ALOR008.64	4ALOR012.20		4ALOR014.33										
CollDate	04/23/07	10/23/07	10/15/08	05/22/08	10/15/08	11/02/94	04/27/95	12/06/95	06/10/97	10/17/97	04/07/99	10/27/99	05/15/00	06/07/11	11/09/11	06/06/12
VSCI Metric Values																
Total Taxa	13	12	12	19	18	11	9	9	13	7	10	11	11	11	16	12
EPT Taxa	7	8	6	9	5	6	6	3	8	4	3	5	6	7	8	6
% Ephemeroptera	29.4	20.6	33.3	20.5	4.4	15.5	24.6	24.7	45.7	8.8	32.0	29.9	18.6	27.3	16.4	46.4
%PT - Hydropsychidae	3.7	8.4	7.1	7.1	4.4	6.8	1.4		5.3	1.3	1.0	3.9	18.6	2.7	20.0	0.9
%Scrapers	14.7	25.2	29.3	8.0	50.9	10.7	10.9	3.2	1.1	7.5	0.0	14.3	0.0	9.1	11.8	4.5
%Chironomidae	39.4	5.6	30.3	27.7	13.2	1.9	29.7	4.3	8.5	16.3	26.2	35.1	18.6	27.3	42.7	26.4
%2 Dominant	56.9	73.8	54.5	50.9	43.0	73.8	72.5	83.9	42.6	73.8	61.2	51.9	54.3	69.1	58.2	60.9
MFBI	5.1	5.0	4.8	5.2	5.6	5.2	5.4	5.6	4.9	5.5	5.3	4.5	4.5	4.0	4.5	5.1
VSCI Metric Scores																
Richness Score	59.1	54.5	54.5	86.4	81.8	50.0	40.9	40.9	59.1	31.8	45.5	50.0	50.0	50.0	72.7	54.5
EPT Score	63.6	72.7	54.5	81.8	45.5	54.5	54.5	27.3	72.7	36.4	27.3	45.5	54.5	63.6	72.7	54.5
%Ephemeroptera Score	47.9	33.5	54.4	33.5	7.2	25.3	40.2	40.3	74.6	14.3	52.3	48.7	30.3	44.5	26.7	75.6
%PT-H Score	10.3	23.6	19.9	20.1	12.3	19.1	4.1	0.0	14.9	3.5	2.7	10.9	52.2	7.7	56.2	2.6
%Scraper Score	28.4	48.9	56.8	15.6	98.6	20.7	21.1	6.3	2.1	14.5	0.0	27.7	0.0	17.6	22.9	8.8
%Chironomidae Score	60.6	94.4	69.7	72.3	86.8	98.1	70.3	95.7	91.5	83.8	73.8	64.9	81.4	72.7	57.3	73.6
%2Dominant Score	62.3	37.8	65.7	71.0	82.4	37.9	39.8	23.3	83.0	37.9	56.1	69.4	66.1	44.7	60.4	56.5
%MFBI Score	72.3	73.1	76.6	71.3	64.5	71.1	67.2	65.3	74.8	66.9	68.7	81.0	81.1	87.6	80.3	71.4
VSCI	**51**	**55**	**57**	**56**	**60**	**47**	**42**	**37**	**59**	**36**	**41**	**50**	**52**	**46**	**56**	**49**
VSCI Rating	**Stressed**	**Stressed**	**Stressed**	**Stressed**	**Stressed**	**Stressed**	**Stressed**	**Severe Stress**	**Stressed**	**Severe Stress**	**Severe Stress**	**Stressed**	**Stressed**	**Stressed**	**Stressed**	**Stressed**

- Primary biological effects.
VSCI: Non-impaired ≥ 60; impaired < 60.

VSCI = Virginia Stream Condition Index
EPT = Ephemeroptera, Plecoptera, and Tricoptera
MFBI = Modified Family Biotic Index

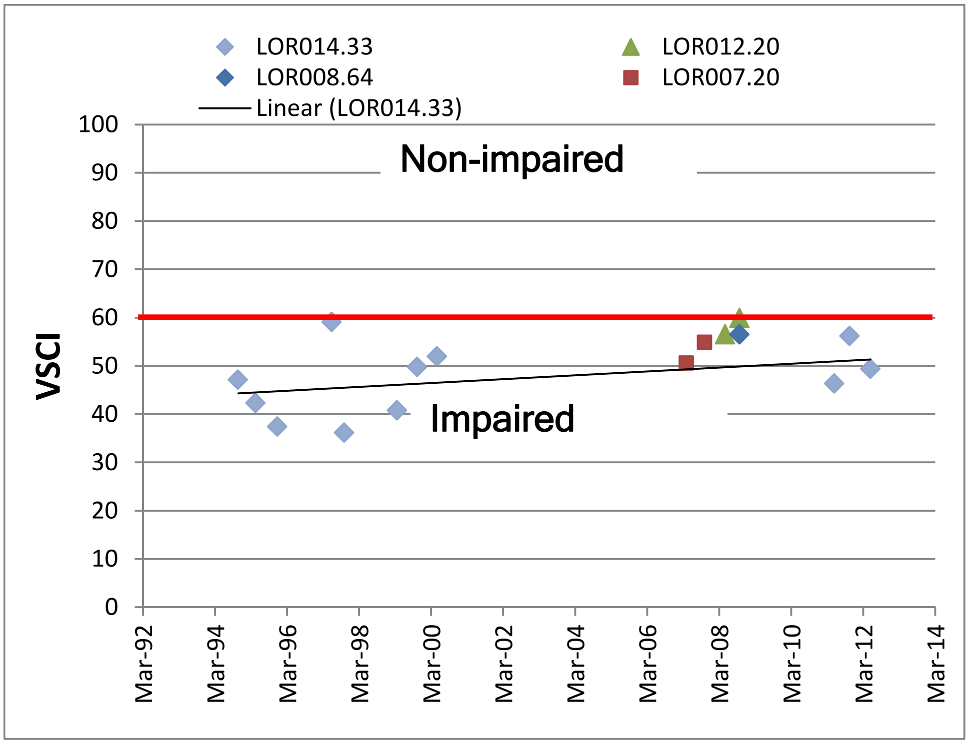


Figure 2-7. VSCI Trend for Lower Little Otter River (LOR)

Buffalo Creek

The biological summaries for Buffalo Creek are in Table 2-11, Table 2-12 and Figure 2-8, including a trend line for the upstream station. The dominant families of benthic macro-invertebrates at the Buffalo Creek site included a balance of mildly pollution-tolerant and mildly pollution-sensitive taxa. Individual VSCI metric scores are on a scale of 0-100, with 100 being the best possible score. The primary biological effects are identified as those metrics scoring in the lowest 20th percentile. The primary biological effects in Buffalo Creek, indicative of its relatively minor impairment, are the occasional low scores for the scraper functional group and the sensitive members of the Plecoptera and Tricoptera families.

Table 2-11. Taxa Inventory by Sample Date in Buffalo Creek (BWA)

Family	Tolerance Value	4ABWA002.00		4ABWA008.53				
		04/02/09	12/02/09	04/02/03	10/06/03	04/02/09	12/02/09	04/17/12
Capniidae	1		2				2	
Gomphidae	1					1		1
Perlidae	1		1			1		
Isonychiidae	2	4	11	2		5	2	2
Nemouridae	2	5		2				
Perlodidae	2	1	1					
Taeniopterygidae	2		3	1				
Philopotamidae	3		4				3	
Tipulidae	3	1	1	1	2	1		
Baetidae	4				2			1
Elmidae	4	7	7	7	1	7	3	6
Ephemerellidae	4	10	1				3	
Heptageniidae	4	9	31	11	2	4	24	37
Pleuroceridae	4			3				
Corydalidae	5	1	1		3		1	1
Ancylidae	6	2	2					
Chironomidae (A)	6	59	23	85	16	65	23	42
Empididae	6	7		4		5	1	
Hydropsychidae	6	3	24	2	54	10	28	7
Simuliidae	6	6	10	1	25	8	7	2
Oligochaeta (unknown)	6					3	6	9
Corbiculidae	8		1				1	1
Sphaeriidae	8	1	1	13		1		1
No. of families		**15**	**17**	**13**	**10**	**12**	**14**	**13**
Abundance		**117**	**124**	**133**	**107**	**111**	**105**	**110**
Additional Benthic Metrics								
Scraper/Filterer-Collector		22.9%	53.3%	20.4%	4.1%	12.0%	38.4%	66.2%
%Filterer-Collector		70.9%	60.5%	77.4%	91.6%	82.9%	69.5%	59.1%
%Haptobenthos		34.2%	66.1%	18.0%	79.4%	27.0%	66.7%	48.2%
%Shredder		5.1%	4.8%	3.0%	1.9%	0.9%	1.9%	0.0%

- Dominant 2 species in each sample.

5 additional taxa were identified with only 1 organism in all samples.

Table 2-12. Biological Index (VSCI) Scores for Buffalo Creek (BWA)

StationID	4ABWA002.00		4ABWA008.53				
CollDate	04/02/09	12/02/09	04/02/03	10/06/03	04/02/09	12/02/09	04/17/12
VSCI Metric Values							
Total Taxa	15	17	13	10	12	14	12
EPT Taxa	7	9	5	3	4	7	4
% Ephemeroptera	19.7	34.7	9.8	3.7	8.1	27.6	36.4
%PT - Hydropsychidae	6.0	8.9	2.3		0.9	5.7	
%Scrapers	16.2	32.3	15.8	3.7	9.9	26.7	39.1
%Chironomidae	50.4	18.5	63.9	15.0	58.6	21.9	38.2
%2 Dominant	59.0	44.4	73.7	73.8	67.6	49.5	71.8
MFBI	5.2	4.7	5.7	5.8	5.5	5.2	5.0
VSCI Metric Scores							
Richness Score	68.2	77.3	59.1	45.5	54.5	63.6	54.5
EPT Score	63.6	81.8	45.5	27.3	36.4	63.6	36.4
%Ephemeroptera Score	32.1	56.6	15.9	6.1	13.2	45.1	59.3
%PT-H Score	16.8	24.9	6.3	0.0	2.5	16.1	0.0
%Scraper Score	31.5	62.5	30.6	7.2	19.2	51.7	75.8
%Chironomidae Score	49.6	81.5	36.1	85.0	41.4	78.1	61.8
%2Dominant Score	59.3	80.4	38.0	37.8	46.9	72.9	40.7
%MFBI Score	70.6	78.4	63.6	61.3	65.8	71.3	73.1
VSCI	**49**	**68**	**37**	**34**	**35**	**58**	**50**
VSCI Rating	**Stressed**	**Good**	**Severe Stress**	**Severe Stress**	**Severe Stress**	**Stressed**	**Stressed**

- Primary biological effects.
VSCI: Non-impaired ≥ 60; impaired < 60.

VSCI = Virginia Stream Condition Index
EPT = Ephemeroptera, Plecoptera, and Tricoptera
MFBI = Modified Family Biotic Index

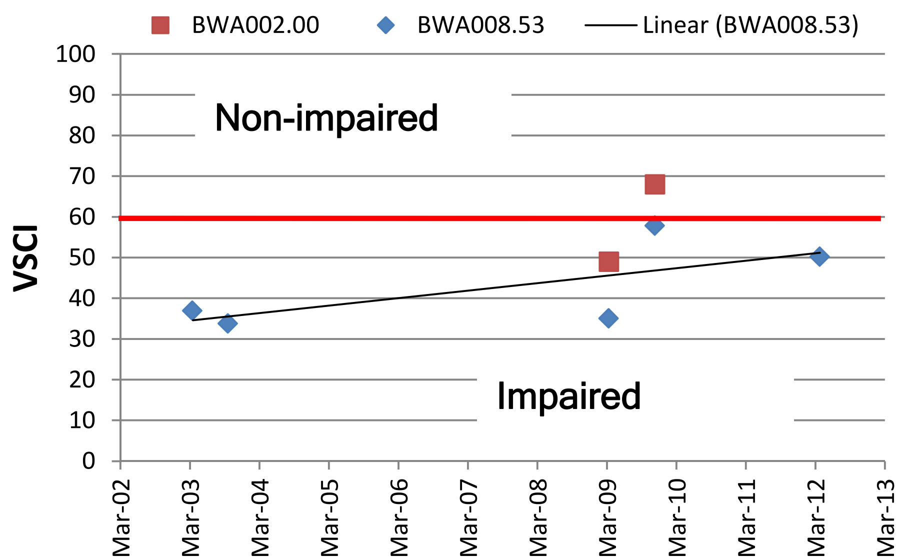


Figure 2-8. VSCI Trend for Buffalo Creek (BWA)

2.8. Biological Monitoring Data – Habitat

A qualitative analysis of various habitat parameters was conducted in conjunction with each benthic macro-invertebrate sampling event. Habitat data collected as part of the biological monitoring were obtained from DEQ through the EDAS database. For each evaluation, ten metrics are scored on a 0-20 basis using EPA rapid biosassessment protocols (Barbour et al., 1999), with scores of 0-5 rated as "poor"; scores of 6-10 as "marginal"; scores of 11-15 as "sub-optimal"; and scores of 16-20 rated as "optimal", with minor variations for those metrics scored separately for each stream bank. The maximum 10-metric total habitat score is 200; scores <120 are considered sub-optimal, and those >150 as optimal. The 10 metrics evaluated vary based on whether the best available habitat was dominated by riffle or multi-habitat (snags, leaf packs). The former is considered "high gradient" and the latter "low gradient."

The habitat assessment data for the Upper Little Otter River are shown in Table 2-13. Scores for all of the "sediment deposition" metric and for all but 2 of the "bank stability" metric were rated as "poor". All of the samples, except the first one and the second to last are rated as "sub-optimal".

Table 2-13. Habitat Metric Scores for Upper Little Otter River (LOR)

StationID	4ALOR014.75											
Collection Date	11/02/94	04/19/95	12/06/95	06/10/97	04/07/99	10/27/99	10/03/06	05/22/08	10/16/08	06/07/11	11/09/11	06/06/12
Channel Alteration	13	12	14	14	10	11	14	20	15	17	17	18
Bank Stability[1]	12	9	7	10	15	7	9	7	4	4	6	4
Vegetative Protection[1]	14	9	8	14	17	8	11	9	8	8	8	6
Embeddedness	15	16	12	9	8	15	7		11		17	
Channel Flow Status	17	12	16	18	19	14	18	15	13	12	17	18
Frequency of riffles (or bends)	10	14	15	6	12	12	12				14	
Riparian Vegetative Zone Width[1]	5	6	2	3	5	6	8	15	14	14	13	14
Sediment Deposition	7	7	6	5	7	8	6	4	6	7	7	5
Epifaunal Substrate / Available Cover	15	16	14	10	10	19	12	10	16	9	11	10
Velocity / Depth Regime	15	17	17	10	15	15	14				16	
Pool Substrate*								7		9		15
Pool Variability*								10	10	9		6
Channel Sinuosity*								10	13	11		8
10-Metric Total Habitat Score[2]	**123**	**118**	**111**	**99**	**118**	**115**	**111**	**107**	**110**	**100**	**126**	**104**

- Marginal or Poor habitat metric rating.

[1] Metric is the sum of scores for both the left and right banks.

[2] Total Habitat Score: optimal > 150; suboptimal < 120.

* Substitute metrics used under "Low Gradient" conditions.

The habitat assessment data for Johns Creek are shown in Table 2-14. The "bank stability" and "sediment deposition" metrics have consistently received "poor" scores, as has "vegetative protection" for all but the first sample. All of the visits to Johns Creek resulted in "sub-optimal" Total Habitat Scores.

Table 2-14. Habitat Metric Scores for Johns Creek (JHN)

StationID	4AJHN000.01								
Collection Date	10/17/97	04/07/99	05/15/00	10/03/06	05/22/08	10/16/08	06/07/11	11/09/11	06/06/12
Channel Alteration	18	16	18	17	17	15	15	15	18
Bank Stability[1]	8	3	2	4	4	5	4	2	2
Vegetative Protection[1]	13	7	2	6	8	5	6	4	6
Embeddedness	6	13	8	13	10	12	10	12	9
Channel Flow Status	10	12	14	14	14	10	16	15	7
Frequency of riffles (or bends)	12	20	15	12	16	15	16	18	16
Riparian Vegetative Zone Width[1]	6	4	11	10	11	10	12	12	12
Sediment Deposition	5	8	7	6	3	9	6	5	6
Epifaunal Substrate / Available Cover	3	12	7	13	8	17	8	11	9
Velocity / Depth Regime	8	15	13	14	14	13	14	16	14
10-Metric Total Habitat Score[2]	**89**	**110**	**97**	**109**	**105**	**111**	**107**	**110**	**99**

- Marginal or Poor habitat metric rating.

[1] Metric is the sum of scores for both the left and right banks.

[2] Total Habitat Score: optimal > 150; suboptimal < 120.

The habitat assessment data for Wells Creek are shown in Table 2-15. The "sediment deposition" metric has consistently received "poor" scores, as have select others from time-to-time. A number of the samples taken at Wells Creek can be rated as "sub-optimal".

Table 2-15. Habitat Metric Scores for Well Creek (WEL)

StationID	4AWEL000.59		4AWEL001.14		
Collection Date	05/25/05	09/19/05	06/13/11	11/15/11	05/07/12
Channel Alteration	20	18	16	18	17
Bank Stability[1]	16	5	10	11	11
Vegetative Protection[1]	14	13	12	13	14
Embeddedness	11	13	9	13	12
Channel Flow Status	15	14	15	15	18
Frequency of riffles (or bends)	15	11	16	15	15
Riparian Vegetative Zone Width[1]	7	5	11	12	14
Sediment Deposition	7	10	4	6	1
Epifaunal Substrate / Available Cover	13	12	10	12	7
Velocity / Depth Regime	16	14	14	10	9
10-Metric Total Habitat Score[2]	**134**	**115**	**117**	**125**	**118**

- Marginal or Poor habitat metric rating.

[1] Metric is the sum of scores for both the left and right banks.

[2] Total Habitat Score: optimal > 150; suboptimal < 120.

The habitat assessment data for the Lower Little Otter River are shown in Table 2-16. While none of the samples have rated "poor" for all habitat metrics, many of the samples have received "poor" scores for the "bank stability", "vegetative protection", and "sediment deposition" metrics. The habitat appears to be slightly better in the downstream section of Lower Little Otter River than upstream.

Table 2-16. Habitat Metric Scores for <u>Lower</u> Little Otter River (LOR)

StationID	4ALOR007.20			4ALOR008.64	4ALOR012.20		4ALOR014.33								
Collection Date	04/23/07	10/23/07	06/07/11	10/15/08	05/22/08	10/15/08	11/02/94	04/27/95	12/06/95	06/10/97	10/17/97	04/07/99	10/27/99	11/09/11	06/06/12
Channel Alteration	20	20	15	15	20	19	17	15	16	13	18	16	12	15	18
Bank Stability[1]	13	13	8	12	5	12	8	8	8	4	5	3	0	6	2
Vegetative Protection[1]	12	15	8	14	14	12	8	9	8	5	5	5	2	8	8
Embeddedness				13			8	11	13	9	10	12	10		
Channel Flow Status	18	14	12	14	18	15	17	16	16	18	13	12	8	15	17
Frequency of riffles (or bends)				12			17	15	15	8	15	20	11		
Riparian Vegetative Zone Width[1]	12	13	19	10	18	19	6	8	2	18	6	1	1	13	7
Sediment Deposition	8	9	6	11	4	7	5	3	6	5	5	6	1	12	10
Epifaunal Substrate / Available Cover	14	17	6	12	10	9	8	7	14	10	9	11	6	16	11
Velocity / Depth Regime				14			16	13	13	10	12	13	8		
Pool Substrate*	16	14	7		7	13								12	11
Pool Variability*	10	7	15		8	13								16	6
Channel Sinuosity*	13	13	13		17	12								11	11
10-Metric Total Habitat Score[2]	**136**	**135**	**109**	**127**	**121**	**131**	**110**	**105**	**111**	**100**	**98**	**99**	**59**	**124**	**101**

- Marginal or Poor habitat metric rating.

[1] Metric is the sum of scores for both the left and right banks.

[2] Total Habitat Score: optimal > 150; suboptimal < 120.

* Substitute metrics used under "Low Gradient" conditions.

The habitat assessment data for Buffalo Creek are shown in Table 2-17. Habitat data collected as part of the biological monitoring were also obtained from DEQ through the EDAS database. The “riparian vegetative zone width”, “bank stability”, and “embeddedness” metrics have occasionally received “poor” scores. The total habitat scores are better at the downstream station (4ABWA002.00) and appear to be quite variable over time at the upstream station (4ABWA008.53). The 10-metric total possible score is 200; scores <120 are considered sub-optimal, and those >150 as optimal.

Table 2-17. Habitat Metric Scores for Buffalo Creek (BWA)

StationID	4ABWA002.00		4ABWA008.53			
Collection Date	04/02/09	12/02/09	04/02/03	04/02/09	12/02/09	04/17/12
Channel Alteration	15	17	15	11	11	16
Bank Stability[1]	11	8	14	7	8	12
Vegetative Protection[1]	11	12	17	10	8	12
Embeddedness	12	8	13	12	8	13
Channel Flow Status	16	18	15	16	18	12
Frequency of riffles (or bends)	14	14	17	11	11	16
Riparian Vegetative Zone Width[1]	10	9	17	10	8	14
Sediment Deposition	11	13	10	10	11	9
Epifaunal Substrate / Available Cover	15	16	15	15	15	15
Velocity / Depth Regime	16	17	18	16	14	16
10-Metric Total Habitat Score[2]	**131**	**132**	**151**	**118**	**112**	**135**

- Marginal or Poor habitat metric rating.

[1] Metric is the sum of scores for both the left and right banks.

[2] Total Habitat Score: optimal > 150; suboptimal < 120.

2.9. Water Quality Data

2.9.1. DEQ Ambient Monitoring Data

Little Otter River

Ambient bi-monthly monitoring has been performed on the Little Otter River impaired segments at various stations and for varying periods at each station since 1992. Field physical parameters include temperature, DO, pH, and conductivity. Chemical parameters include: nitrogen (N) species - ammonia-N, nitrate-N, nitrite-N, TKN, and total N; total phosphorus (P); total filterable residue (suspended solids); chloride; and bacteria fecal coliform and Escherichia coli. Average nutrient concentrations at the various stations are summarized in Table 2-18, along with two calculated ratios to assist in assessing nutrient influences in these watersheds.

Table 2-18. Nutrient Concentration Averages and Ratios

Station ID	Beg. Date	End Date	NITROGEN, TOTAL (mg/L)		NITRATE NITROGEN (mg/L)		NITROGEN, KJELDAHL TOTAL (mg/L)		PHOSPHORUS, TOTAL (mg/L)		TN:TP Ratio	TKN:TN Ratio
			No.	Ave.	No.	Ave.	No.	Ave.	No.	Ave.		
4AJHN000.01	Mar-00	Nov-11	4	0.5	4	0.3	4	0.4	6	0.1	9.55	0.76
4ALOR007.20	Apr-07	Oct-07	2	1.6	2	1.4	2	0.4	2	0.4	4.19	0.25
4ALOR008.64	Jul-96	Apr-12	21	2.5	74	1.5	75	0.6	95	0.3	7.99	0.24
4ALOR010.78	Aug-92	Apr-00			38	1.1	38	0.5	38	0.3	5.08	0.31
4ALOR014.33	Jun-90	Nov-11	2	3.4	24	3.3	25	1.7	27	0.7	4.91	0.49
4ALOR014.75	Jan-90	Apr-12	53	0.9	159	0.7	186	0.4	213	0.1	9.47	0.43
4ALOR018.96	Apr-00	Apr-00			1	0.6	1	0.3	1	0.1	15.50	0.32
4ALOR021.92	Apr-00	Dec-08	12	1.6	1	0.4	1	0.3	13	0.1	11.79	0.19
4AMCR004.60	Aug-92	Apr-12	32	0.9	20	0.5	20	0.4	52	0.1	14.67	0.49
4AWEL000.59	May-05	May-05	1	1.2	1	0.7	1	0.3	1	0.1	19.33	0.26
4AWEL001.14	Apr-00	Apr-12	8	1.3	1	0.4	1	0.4	9	0.1	11.29	0.30
4AXOD000.38	May-11	Oct-11	2	1.3	2	1.1	2	0.3	2	0.1	9.81	0.20

- Indicates elevated values.

Plots of monthly ambient water quality monitoring parameters are shown in the following figures for available data from January 1994 through April 2012. Plots are grouped by parameter for stations on the Upper LOR (Little Otter River), the Lower LOR stations, Johns Creek, and Wells Creek sub-watersheds. Where few or no samples were available at monitoring stations in a given sub-watershed, a summary of the data are given instead. Data for Machine Creek (MCR) are included in the analysis as Machine Creek is the tributary link between Wells Creek and the Lower LOR.

The parameter shown in the plots include: temperature (Figures 2-9 to 2-12); dissolved oxygen (Figures 2-13 to 2-16); pH (Figures 2-17 to 2-20); specific conductivity (Figures 2-21 to 2-24); nitrogen (Upper LOR: Figures 2-25 to 2-26; Lower LOR: Figures 2-27 to 2-28); total phosphorus (Upper LOR: Figures 2-29; Lower LOR: Figures 2-30); total filterable residue, also called suspended solids (Upper LOR: Figures 2-31; Lower LOR: Figures 2-32); chloride (Upper LOR: Figures 2-33; Lower LOR: Figures 2-34), fecal coliform (Upper LOR: Figures 2-35; Lower LOR: Figures 2-36), and *Escherichia coli* (Upper LOR: Figures 2-37; Lower LOR: Figures 2-38).

Where applicable, minimum and/or maximum water quality standards, minimum detection limits (MDL), and sample analysis caps are indicated on the plots. All stream segments within these watersheds are Class III Nontidal Waters, Coastal and Piedmont Zones (SWCB, 2011).

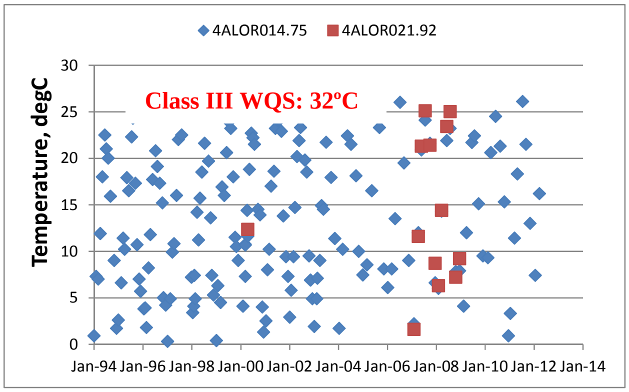


Figure 2-9. Field Temperature - Upper LOR

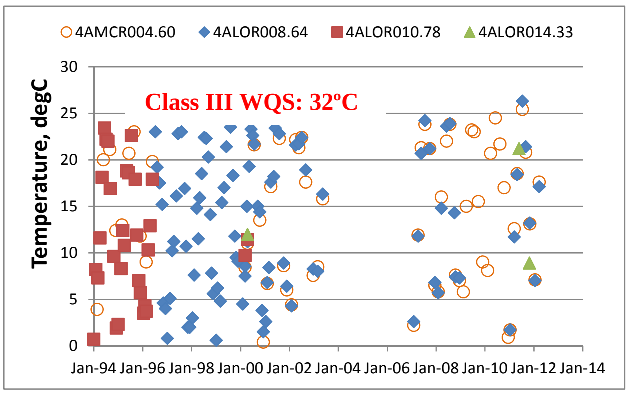


Figure 2-10. Field Temperature - Lower LOR

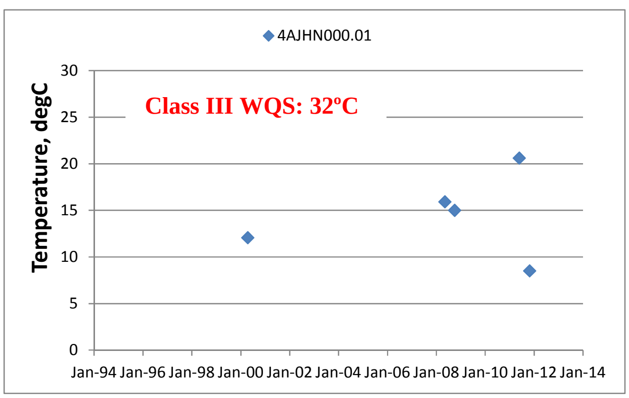


Figure 2-11. Field Temperature - Johns Creek

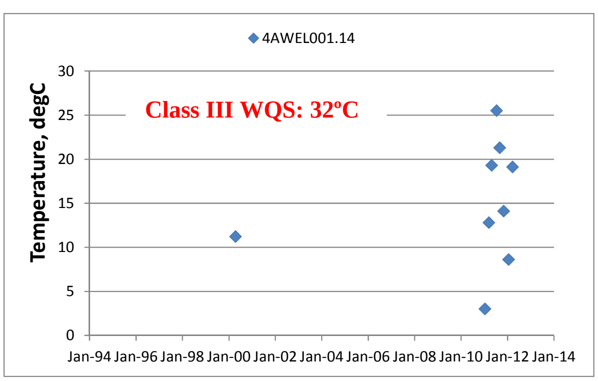


Figure 2-12. Field Temperature - Wells Creek

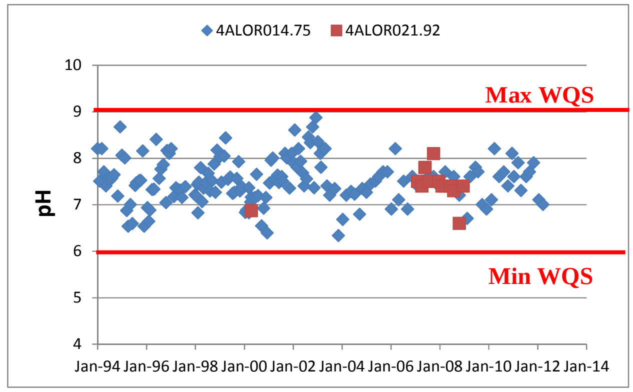


Figure 2-13. Field pH - Upper LOR

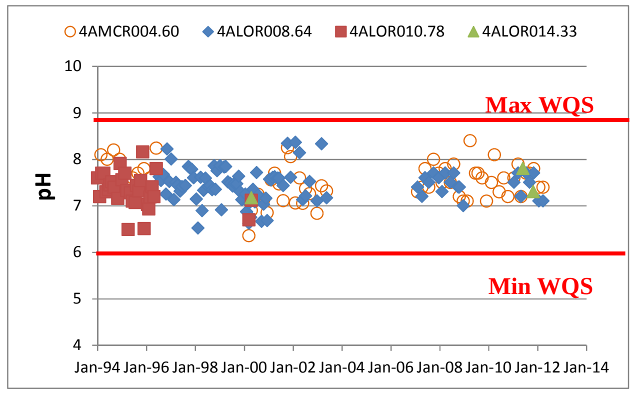


Figure 2-14. Field pH - Lower LOR

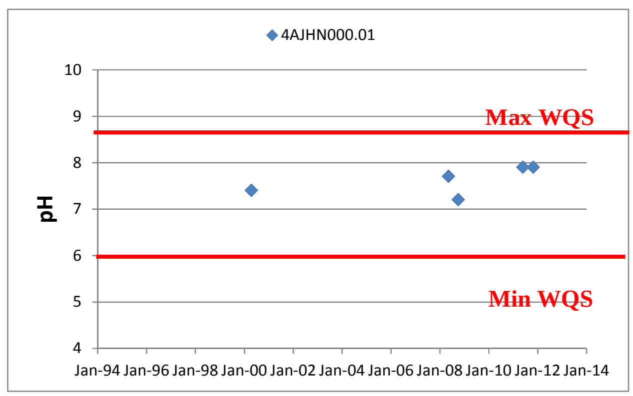


Figure 2-15. Field pH - Johns Creek

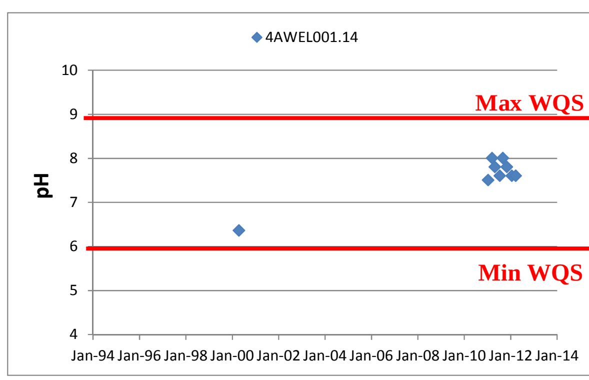


Figure 2-16. Field pH - Wells Creek

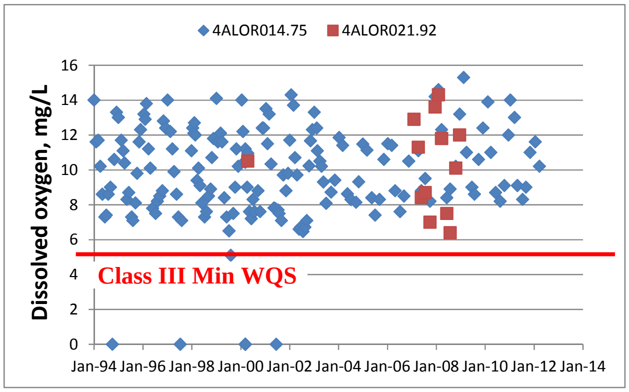


Figure 2-17. Field DO - Upper LOR

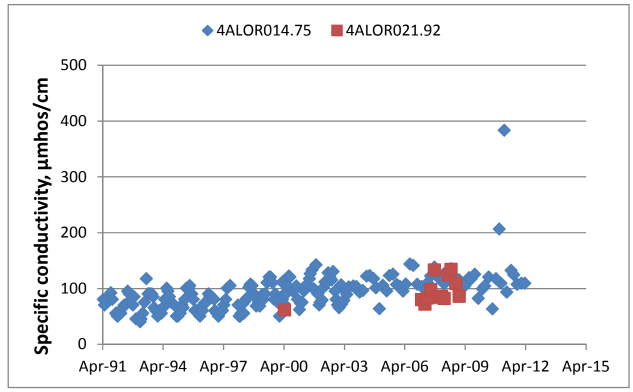


Figure 2-21. Specific Conductivity - Upper LOR

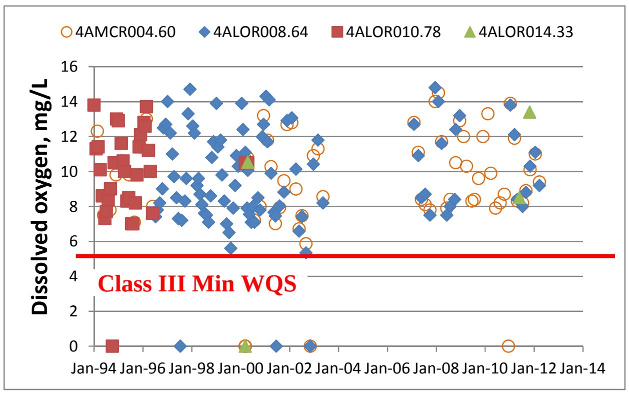


Figure 2-18. Field DO - Lower LOR

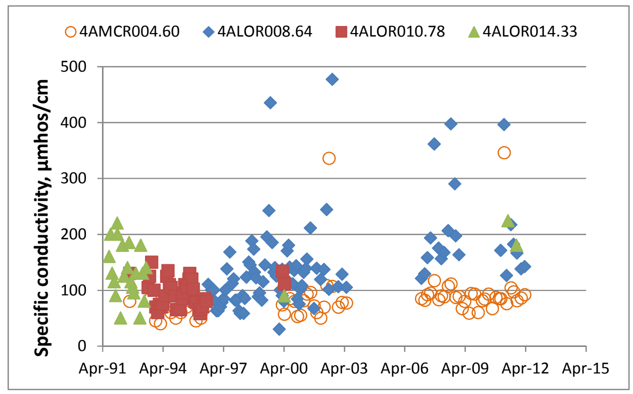


Figure 2-22. Specific Conductivity - Lower LOR

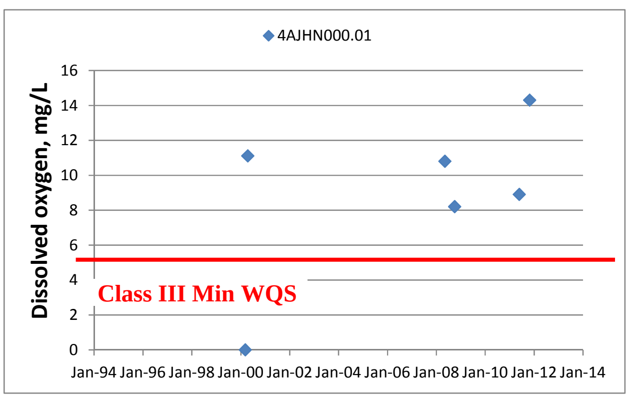


Figure 2-19. Field DO - Johns Creek

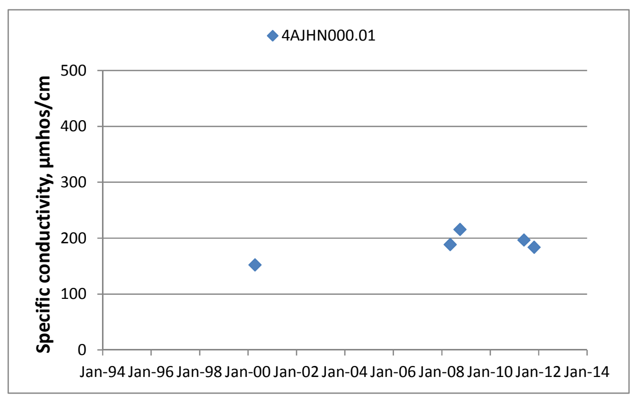


Figure 2-23. Specific Conductivity - Johns Creek

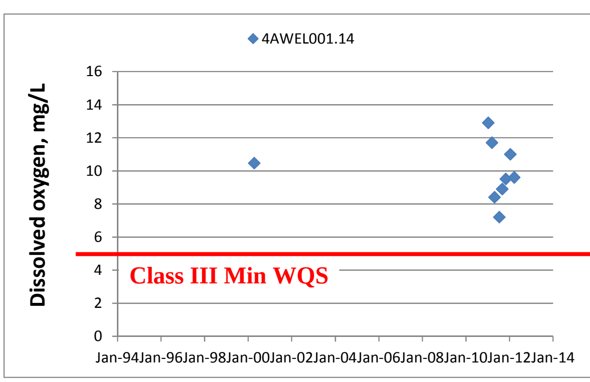


Figure 2-20. Field DO - Wells Creek

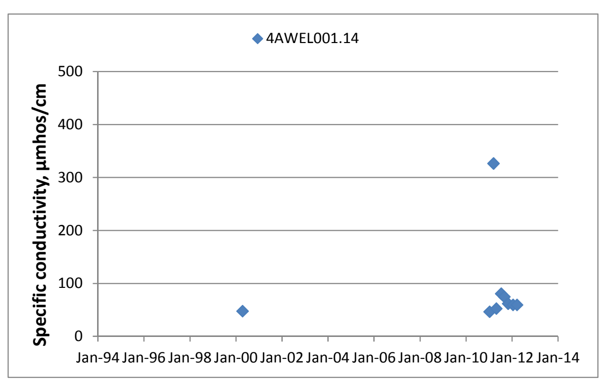


Figure 2-24. Specific Conductivity - Wells Creek

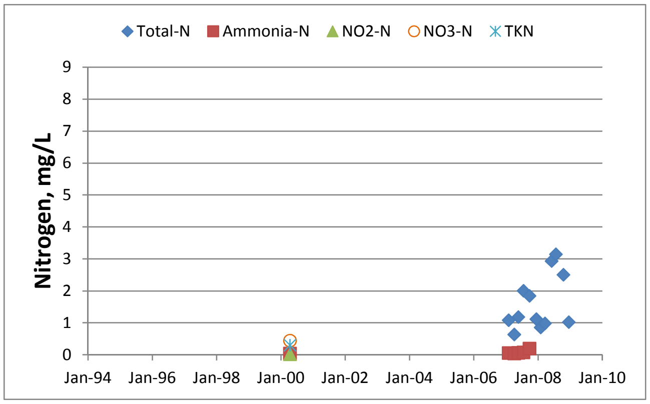


Figure 2-25. Nitrogen - Upper LOR (4ALOR021.92)

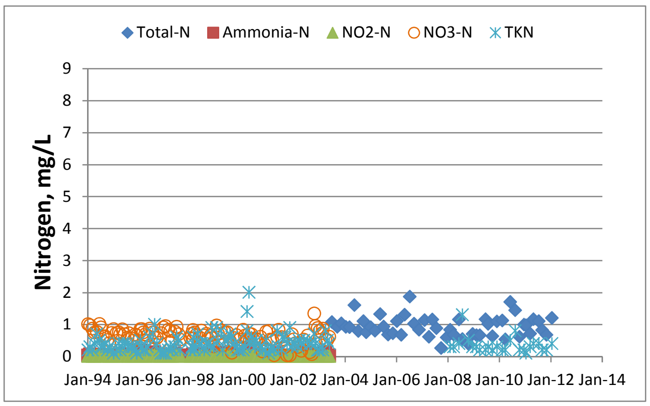


Figure 2-26. Nitrogen - Upper LOR (4ALOR014.75)

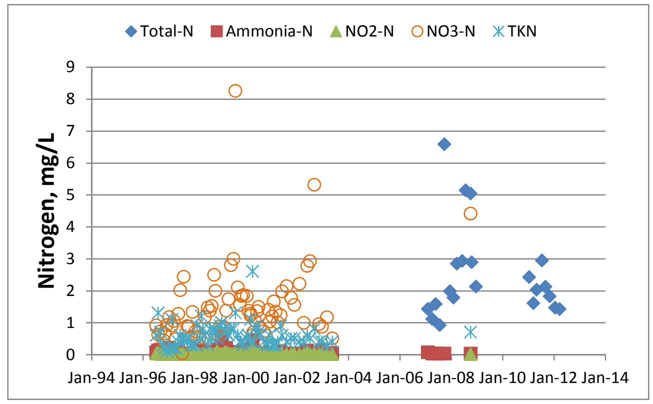


Figure 2-27. Nitrogen - Lower LOR (4ALOR008.64)

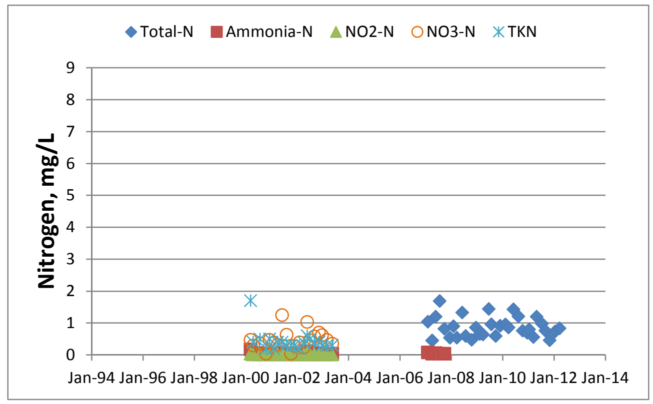


Figure 2-28. Nitrogen - Lower LOR (4AMCR004.60)

- Other Nitrogen Data
  - Other Lower LOR stations
    - 4ALOR014.33: 27 samples taken pre-1994, several > 10 mg/L; 2 samples in 2000; 2 samples in 2011, averaging 2.64 mg/L.
    - 4ALOR010.78: 37 samples taken pre-1996, averaging 1.69 mg/L; 2 samples in 2000 averaged 1.73 mg/L.
  - Johns Creek: 6 samples, all < 1.0 mg/L.
  - Wells Creek: 8 samples, only 1 sample > 2 mg/L.

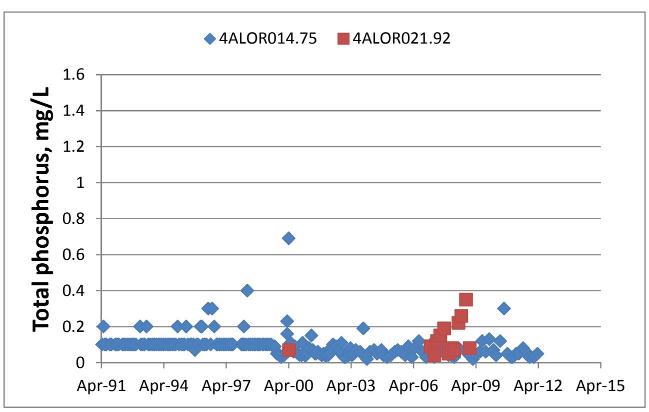


Figure 2-29. Total Phosphorus - Upper LOR

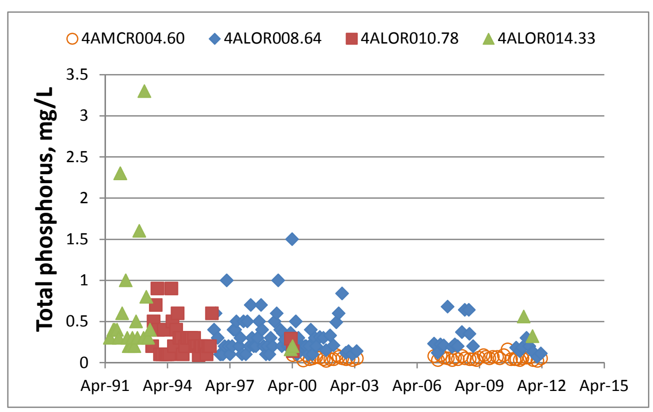


Figure 2-30. Total Phosphorus - Lower LOR

- Other Total Phosphorus Data
  - Johns Creek: 6 samples, averaging 0.055 mg/L.
  - Wells Creek: 9 samples averaging 0.119 mg/L, 1 sample > 0.2 mg/L.

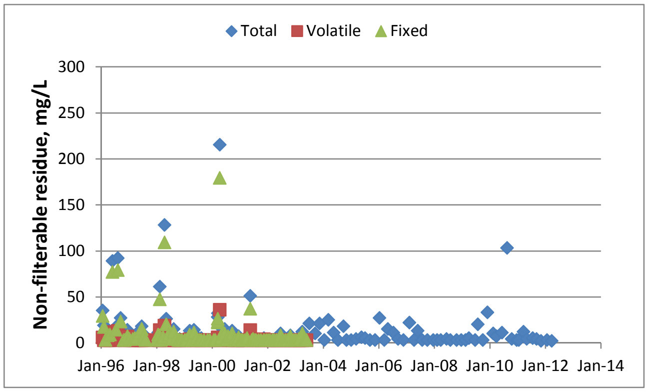


Figure 2-31. Non-filterable residue - 4ALOR014.75

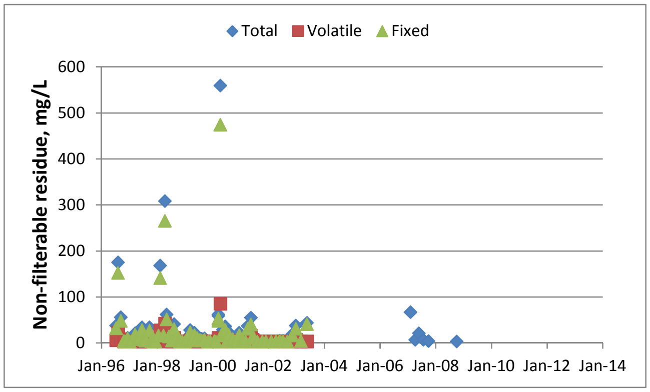


Figure 2-32. Non-filterable residue - 4ALOR008.64

- Other Non-Filterable Residue Data
  - Johns Creek: 3 samples, averaging 9 mg/L.
  - Wells Creek: 2 samples averaging 13 mg/L.
  - Machine Creek: 25 samples averaging 10 mg/L.
  - VA0022390 (Bedford City STP): Jun-00 and Aug-00 samples averaging 3 mg/L.
  - VA0087840 (Dillons Trailer Park STP): Jan-02 sample at 38 mg/L.

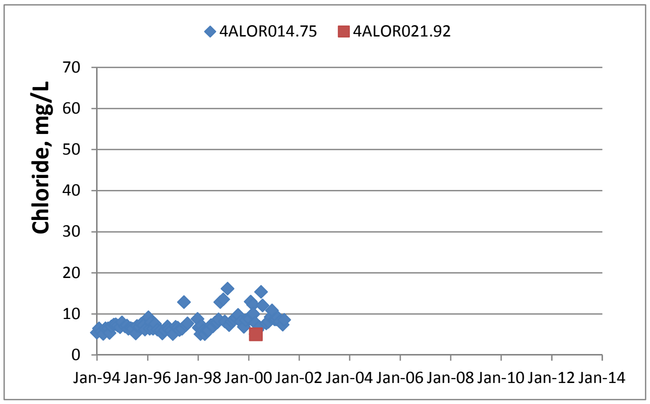


Figure 2-33. Chloride - Upper LOR

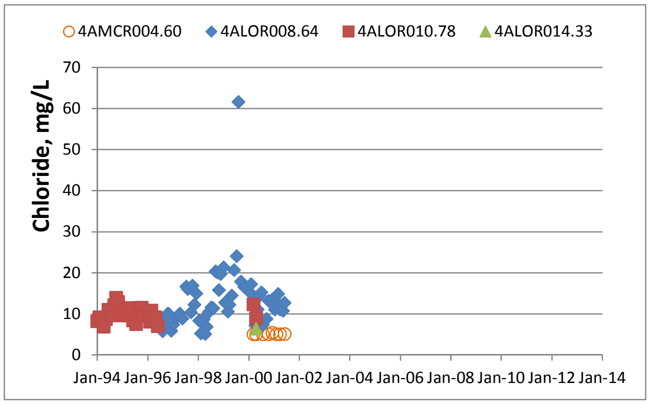


Figure 2-34. Chloride - Lower LOR

- Other Chloride Data
  - Johns Creek: 2 samples, averaging 12.2 mg/L.
  - Wells Creek: 1 sample at 5 mg/L.

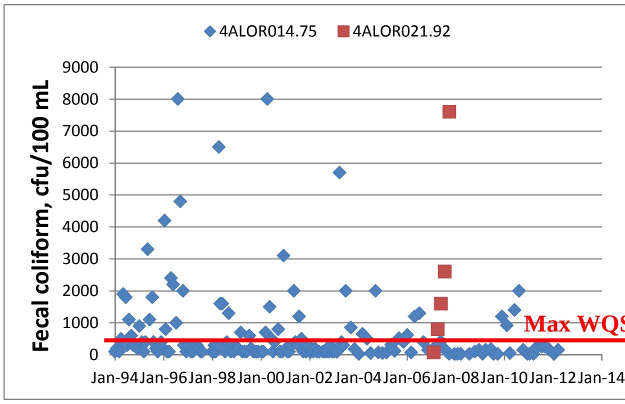


Figure 2-35. Fecal coliform Bacteria - Upper LOR

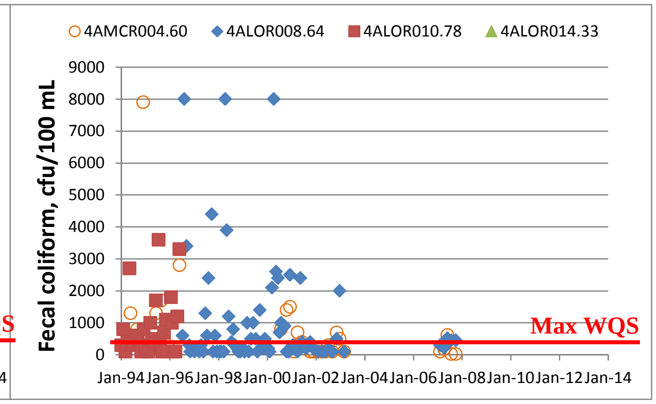


Figure 2-36. Fecal coliform Bacteria - Lower LOR

- Other Fecal Coliform Data
    - o Johns Creek: 1 sample at 300 cfu/100 mL.
    - o Wells Creek: no data.

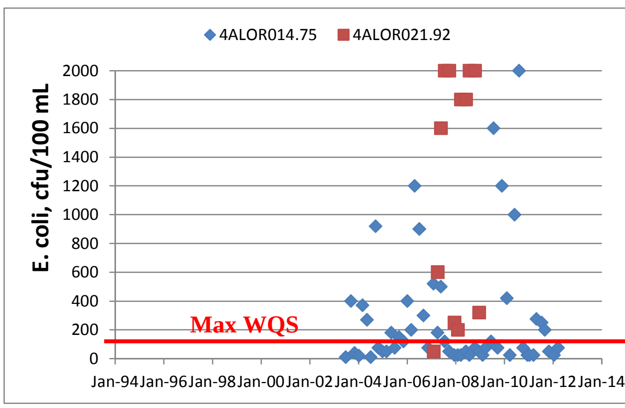


Figure 2-37. *Escherichia coli* Bacteria - Upper LOR

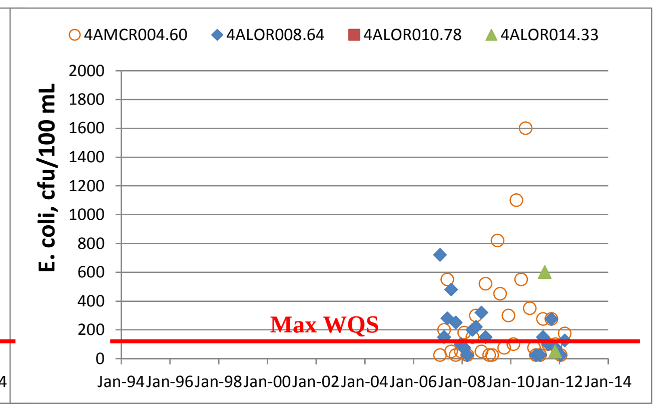


Figure 2-38. *Escherichia coli* Bacteria - Lower LOR

- Other *Escherichia coli* Data
    - o Johns Creek: 1 sample at 80 cfu/100 mL.
    - o Wells Creek: 8 samples, averaging 816 cfu/100 mL.

Buffalo Creek

Ambient bi-monthly monitoring has been performed on the Buffalo Creek impaired segment at the 4ABWA002.00 ambient station since July 2003, once at the 4ABWA007.87 station in April 2000, and once at station 4ABWA008.53 in April 2003.

Nutrient data in Buffalo Creek are summarized in Table 2-19 to assist in assessing nutrient influences in these watersheds.

Table 2-19. Nutrient Concentration Averages and Ratios

Station	Period	TN		NO2+NO3-N		TKN		TP		TN:TP	TKN:TN
		No.	Ave.	No.	Ave.	No.	Ave.	No.	Ave.	Ratio	Ratio
4ABWA002.00	2003-2005	12	0.77	0		0		12	0.039	19.74	
	2007-2009	18	0.67	0		0		18	0.028	23.57	
	2010-2012	13	0.80	0		0		14	0.036	21.96	
4ABWA007.87	2000	1	0.84	1	0.38	1	0.4	1	0.040	21.00	0.48
4ABWA008.53	2003	1	0.82	1	0.35	1	0.3	1	0.010	82.00	0.37

Where applicable, minimum and/or maximum water quality standards, minimum detection limits (MDL), and sample analysis caps are indicated on the plots. All stream segments within these watersheds are Class III Nontidal Waters, Coastal and Piedmont Zones (SWCB, 2011).

Plots of monthly ambient water quality monitoring sample data for the ambient monitoring station in Buffalo Creek are shown in Figure 2-39 through Figure 2-46.

Field physical parameters include temperature, pH, DO, and conductivity. Chemical parameters include: total N; total P; ammonia (only 1 of 18 samples above the minimum detection limit – data not shown); total nonfilterable residue (suspended solids); and bacteria (fecal coliform [only 6 samples – data not shown] and Escherichia coli).

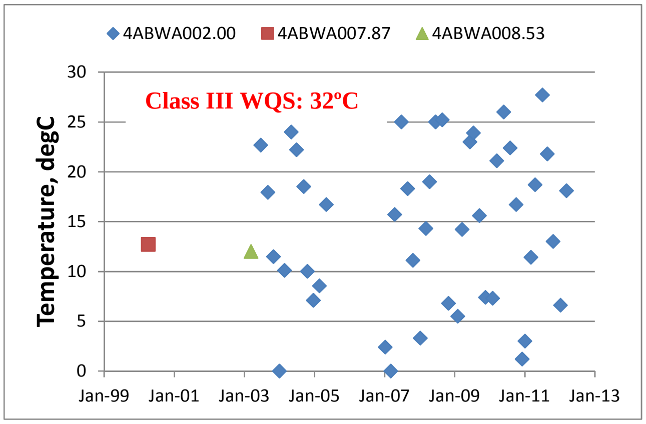


Figure 2-39. Field Temperature

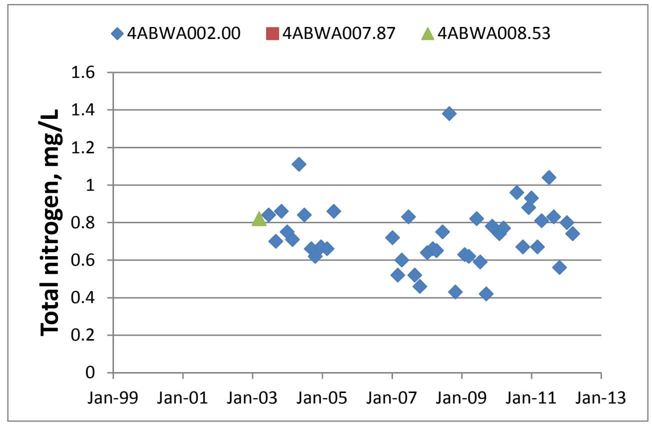


Figure 2-42. Nitrogen

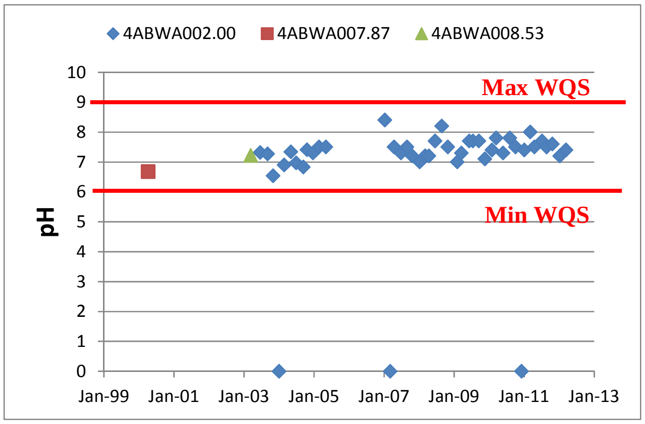


Figure 2-40. Field pH

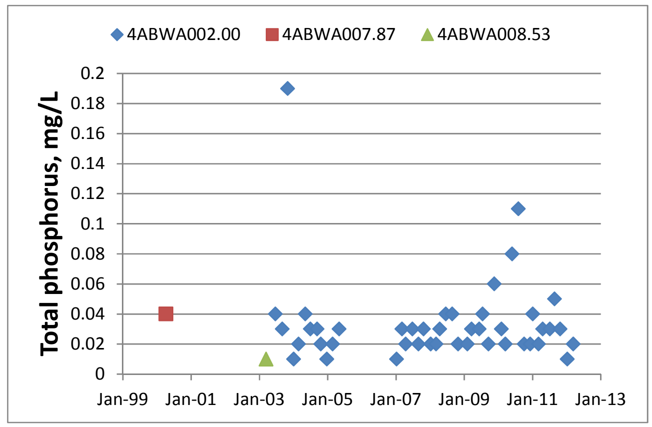


Figure 2-43. Phosphorus

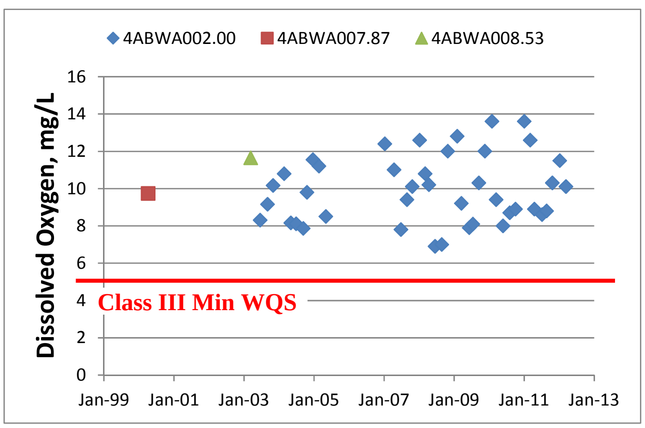


Figure 2-41. Field DO

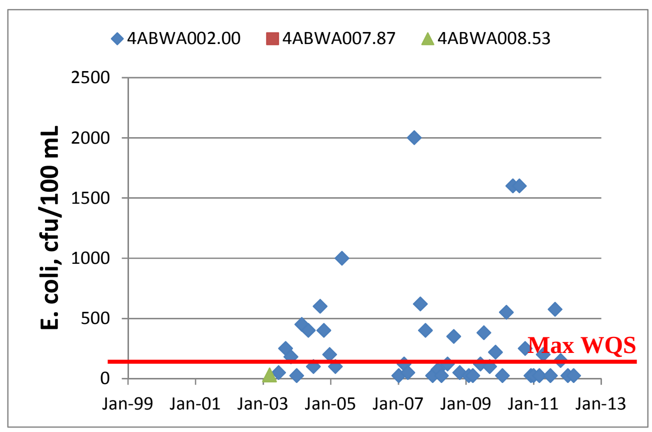


Figure 2-44. Escherichia coli Bacteria

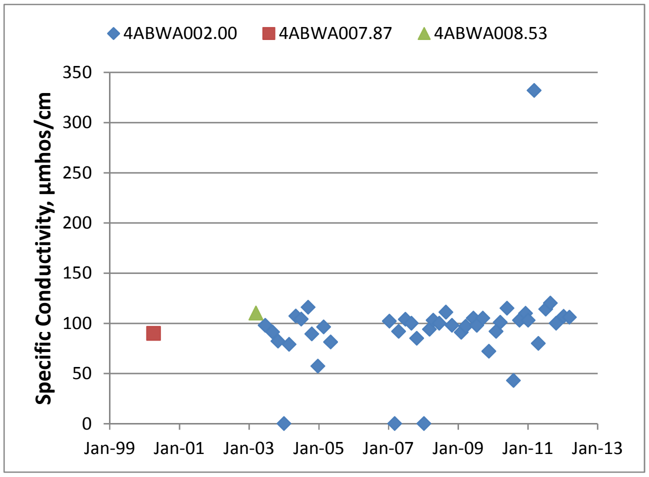


Figure 2-45. Specific Conductivity

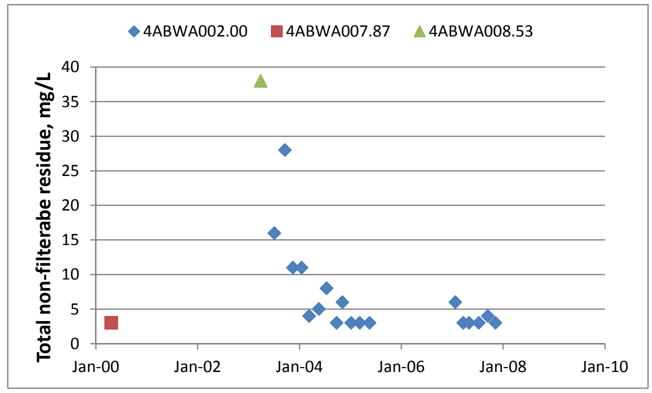


Figure 2-46. Non-filterable residue

Summaries of violations of water quality standards based on DEQ monitoring are included in the state's biennial 305(b)/303(d) Combined Report, as shown in Table 2-20.

In the Little Otter River and tributaries, in addition to the biological monitoring reported previously, the bacteria exceedences being addressed by the Big Otter River IP, and the PCB impairment in the Little Otter River being addressed in the Roanoke (Staunton) River PCB TMDL, the following water quality standards exceedences have been reported in these reports:

- Total Phosphorus: multiple exceedences at various upstream and downstream stations on the main channel of the Little Otter River, all reported prior to 2004.
- Metals in Fish Tissue: two violations on the Little Otter River at different stations prior to 2002.
- Metals and Organics in Benthic Organisms: 1 violation of organics has occurred at station 4ALOR007.94 during each assessment since 2002, leading to it being assessed as impaired for organics beginning in 2006. Beginning in 2008, the same station has been assessed as impaired for metals in benthics.

In Buffalo Creek, the following water quality exceedences were reported:

- Bacteria: a bacterial impairment at station 4ABWA002.00 beginning in the 2006 report.
- pH: Two minor pH violations were reported around Timber Lake by citizen monitoring, once in 2006 and once in 2007.

Table 2-20. Summary of 305(b)/303(d) Integrated Report Monitored Exceedences

Year	Monitoring Station	Type	CONVENTIONAL WATER COLUMN									OTHER WATER COLUMN DATA						SEDIMENT				FISH TISSUE				BENTHIC				Bio Mon Status
			#Violations/# Samples/Status									#Violations/# Samples/Status						#Violations/Status				#Violations/Status				#Violations/Status				
			Temperature			Dissolved Oxygen			pH			Total Phosphorus			Chlorophyll A			Metals		Organics		Metals		Organics		Metals		Organics		
2002	4AJHN000.01	B,TM	0	3	S	0	3	S	0	3	S	0	2	S						0	S									IM
	4ALOR007.94	C,SS																				0	S	0	S	0	S	1	P	
	4ALOR008.64	A,TM	0	54	S	0	54	S	0	54	S	29	56	T						0	S	1	T	0	S					
	4ALOR010.78	A,TM	0	7	S	0	7	S	0	7	S	2	8	T						0	S									
	4ALOR014.33	B,TM	0	5	S	0	5	S	0	4	S	0	2	S						0	S									IM
	4ALOR014.75	A,B,TM	0	63	S	0	63	S	0	62	S	4	61	S						0	S	1	T	0	S					S
	4ALOR018.96	TM	0	1	W	0	1	W	0	1	W	0	1	W						0	S									
	4ALOR021.92	TM	0	1	W	0	1	W	0	1	W	0	1	W						0	S									
	4AMCR004.60	A,TM	0	6	S	0	6	S	0	6	S	1	5	S						0	S									
	4AWEL001.14	TM	0	1	W	0	1	W	0	1	W	0	1	W						0	S									
2006	4AJHN000.01	B/TM	0	2	S	0	2	S	0	2	S	0	2	S						0	S									IM
	4ALOR007.94	C																				0	S	0	S	0	S	1	IM	
	4ALOR008.64	A/TM	0	28	S	0	28	S	0	28	S	15	32	O	0	8	S	0	S			0	S	0	S					
	4ALOR010.78	A/TM	0	2	S	0	2	S	0	2	S	1	2	IN				0	S											
	4ALOR014.33	B/TM	0	2	S	0	2	S	0	2	S	0	2	S				0	S											IM
	4ALOR014.75	A/B/TM	0	52	S	0	52	S	0	52	S	2	53	S	0	13	S	0	S	0	S	0	S	0	S					S
	4ALOR018.96	TM	0	2	S	0	2	S	0	2	S	0	2	S						0	S									
	4ALOR021.92	TM	0	2	S	0	2	S	0	2	S	0	2	S						0	S									
	4AMCR004.60	A/TM	0	17	S	0	17	S	0	17	S	1	20	S						0	S									
	4AWEL001.14	TM	0	1	W	0	1	W	0	1	W	0	1	W						0	S									
2008	4AJHN000.01	B,TM	0	1	S	0	1	S	0	1	S																			IM
	4ALOR007.94	C																				0	S	0	S	1	O	1	IM	
	4ALOR008.64	A,TM	0	14	S	0	14	S	0	14	S							0	S											
	4ALOR014.75	A,B,TM,TR	0	49	S	0	49	S	0	49	S							0	S	0	S									IM
	4AMCR004.60	A,TM	0	12	S	0	12	S	0	12	S									0	S									
	4AWEL000.59	FPM	0	2	S	0	2	S	0	2	S																			IM
2010	4AJHN000.01	B,FPM,TM	0	3	S	0	3	S	0	3	S							0	S	0	S	0	S							IM
	4ALOR007.20	FPM,B	0	2	S	0	2	S	0	2	S							0	S	0	S	0	S							IM
	4ALOR007.94	C																				0	S	0	S	1	IM	1	IM	
	4ALOR008.64	A,B,TM	0	16	S	0	16	S	0	16	S							0	S											IM
	4ALOR012.20	B,TM	0	2	S	0	2	S	0	2	S																			IM
	4ALOR014.75	A,B,TM,TR	0	42	S	0	42	S	0	42	S									0	S									IM
	4ALOR021.92	TM	0	12	S	0	12	S	0	12	S																			
	4AMCR004.60	A,TM	0	15	S	0	15	S	0	15	S									0	S									

Impaired Waters

A = DEQ Ambient Monitoring Station
B = DEQ Biological Monitoring Station
FPM = Freshwater Probabilistic Monitoring Station
MP = Citizen Monitoring – Medium Priority for Adverse Conditions
TM = DEQ TMDL monitoring station
TR = DEQ Ambient Trend Station

W = Not Assessed
IM = Impaired
S = Supporting

2.9.2. DEQ Stream Tests for Metals and Organic Compounds

Little Otter River

Twenty-six sediment samples have been collected over time in the encompassing Little Otter River watershed and analyzed by DEQ for a standard suite of metals; 1 in Johns Creek, 14 in Lower Little Otter River, 10 in the Upper Little Otter River, and 1 in Wells Creek.

Only one of the tested substances, zinc, exceeded any established consensus-based probable effects concentration (PEC) screening criteria. That sample was taken in 1993 and all subsequent samples showed more typical concentrations for that site.

Most of the metals were not detected above their respective minimum detection limit (MDL), as shown in Table 2-21. In addition to the metal parameters listed in the table, up to 24 other metal and/or organic compounds in each sample were analyzed with no detects in any sample.

Table 2-21. DEQ Channel Bottom Sediment Monitoring and Screening Criteria for Metals

Station ID	Collection Date	Metals Measured in Stream Channel Bottom Deposits								
		01029	01043	01052	01053	01068	01093	01098	01108	01170
		Chromium	Copper	Lead	Manganese	Nickel	Zinc	Antimony	Aluminum	Iron
		(mg/kg, dry weight)								
4AJHN000.01	05/22/08	18	7.34	9.95	347	5.05	65.5	U	15900	29600
4AMCR004.60	06/01/94	28	8	6	0	7	16	0	0	0
	06/19/95	19	U	U	174	U	U	7	3670	9700
	12/04/95	23	U	6	169	U	8	5	2410	6740
4ALOR007.20	04/23/07	17	U	7.8	247	U	33.3	U	7940	16100
4ALOR008.64	07/17/96	15	U	U	156	U	23	U	4690	10300
	07/21/97	13	U	9	184	U	33	U	7321	14865
	07/21/98	19.9	5.2	12.4	330	5.4	54.7	U	19100	20800
	05/22/00	16.9	U	7.7	156	U	30.7	U	8700	11300
4ALOR010.78	07/20/93	17	5	10	0	5	49	0	0	0
	03/22/95	21	8	8	216	U	33	8	8390	14000
	09/19/95	25	10	10	341	9	70	19	16600	28600
4ALOR014.33	03/26/91	19	6	11	0	5	48	0	0	0
	06/09/92	27	17	14	0	6	90	0	0	0
	07/13/92	21	7	13	0	8	74	0	0	0
4ALOR014.75	06/22/92	16	U	10	0	U	22	0	0	10000
	07/13/92	16	U	15	0	U	23	0	0	0
	07/20/93	14	U	10	0	U	680	0	0	0
	03/22/95	13	8	13	204	U	25	6	5910	10800
	09/19/95	13	6	7	220	U	34	9	8330	14500
	07/17/96	18	11	13	399	8	75	5	17300	29500
	07/21/97	14	U	11	243	U	26	U	5505	11675
	07/21/98	12	U	16.4	160	U	26.4	U	4410	7450
	05/22/00	14.7	U	8.8	152	U	20.8	U	5210	9510
4AXOD000.38	05/03/11	6.5	QQ	7.98	236	QQ	51.7	QQ	11500	18600
4AWEL000.59	05/25/05	39.6	11.1	6.44	343	9.72	46.6	U	11800	22700
Consensus-based TEC (mg/kg)		43.4	31.6	35.8	--	22.7	121	--	--	--
Consensus-based PEC (mg/kg)		111	149	128	--	48.6	459	--	--	--

U = parameter analyzed, but not detected.
QQ = Analyte detected above the MDL but below the method quantification limit.
TEC = Threshold effects concentration; PEC = Probable effects concentration.
In addition to the parameters listed above, up to 24 parameters in each sample were analyzed with no detects in any sample; however, not all parameters were analyzed in each sample.

Seven samples, taken on the same day as one of the sediment metals samples, were analyzed for dissolved metals. These results are shown in Table 2-22. Only one sample exceeded any of the applicable aquatic life, human health, or EPA nationally recommended freshwater criteria (a historical Upper Little Otter River sample in July 1993 with the exceeding parameter being zinc). Additionally, all of the samples were analyzed for cadmium, lead, thallium, and silver without any detections.

Table 2-22. Dissolved Metals Monitoring and Screening Criteria

	4AJHN000.01	4ALOR007.20	4ALOR008.64	4ALOR014.75		4AWEL000.59	4AXOD000.38	AQUATIC LIFE		HUMAN HEALTH		EPA FRESHWATER	
								FRESHWATER		Public Water	All Other Surface	acute	chronic
	05/22/08	04/23/07	06/27/01	06/27/01	06/25/02	05/25/05	05/03/11	Acute	Chronic	Supply	Waters	CMC	CCC
Name								All units in μg/L, except for observed mercury (ng/L).					
CALCIUM, DISSOLVED (MG/L AS CA)	20.2	10.0	10.2	8.6	9.4	5.0	15.1						
MAGNESIUM, DISSOLVED (MG/L AS MG)	4.4	3.1	3.9	2.3	3.2	2.3	3.9						
ARSENIC, DISSOLVED (UG/L AS AS)	0.1	0.1	0.4	0.3	0.4	0.1	QQ	340	150	10	0	0	0
BARIUM, TOTAL (UG/L AS BA)	48.7						54.6						
CHROMIUM, DISSOLVED (UG/L AS CR)	1.4	0.5	0.1	0.1	0.1	0.1	1.7	570	10				
COPPER, DISSOLVED (UG/L AS CU)	0.5	0.6	0.8	0.5	0.3	0.4	0.2	13	9	1300	0	13	9
IRON, DISSOLVED (UG/L AS FE)	73.6	199.0	53.7	72.5	100.0	120.0	QQ			300		0	1000
MANGANESE, DISSOLVED (UG/L AS MN)	20.6	20.4	27.7	19.8	138.0	42.5	10.3		0	50	0	0	0
NICKEL, DISSOLVED (UG/L AS NI)	0.1	0.2	0.3	0.2	0.2	0.3	0.5	180	20	610	4600	470	52
ZINC, DISSOLVED (UG/L AS ZN)	1.0	1.0	1.0	1.0	1.1	1.0	3.4	120	120	7400	26000	120	120
ANTIMONY, DISSOLVED (UG/L AS SB)	0.5	0.5	0.2	0.1	0.1	0.5	QQ			5.6	640	0	0
PHENANTHRENE DRY WGTBOTUG/KG						18.0							
MERCURY-TL,ULTRATRACE METHOD NG/L	1.5	1.5	1.5	1.5	3.6	1.5	4.4	1.4	0.77	0	0	0	0

- Sample concentrations below minimum limits of detection.
- Sample concentration exceeding one or more criteria.

CMC = criteria maximum concentration (acute criterion)
CCC = criterion continuous concentration (chronic criterion)
QQ = Analyte detected above the MDL but below the method quantification limit.

Heavy metals such as mercury, chromium, cadmium, arsenic and lead in streams and rivers can damage aquatic insects at low concentrations. The metals tend to accumulate in the gills and muscles of aquatic organisms. Dissolved metals have been identified as important predictors of stream health. In the context of water quality criteria, dissolved metals are typically treated independently; however there is strong evidence that metals have a cumulative effect (Clements et al., 2000). The Cumulative Criterion Units (CCU) metals index accounts for this additive effect by standardizing each dissolved metal's concentration. The metals are summed together and the result is the CCU Metals Index score. When the CCU Metals Index is above 2, the cumulative effect is considered likely to harm aquatic life (Clements et al., 2000). The average CCU score for the sets of dissolved metals samples in Table 2-22 was 0.18, ranging between 0.09 and 0.22, well below the threshold of concern.

<u>Buffalo Creek</u>

One sediment sample was collected for Buffalo Creek watershed and analyzed by DEQ for a standard suite of metals. None of the tested substances exceeded any established consensus-based probable effects concentration (PEC) screening criteria, and most of the metals were not detected above their respective minimum detection limit (MDL), as shown in Table 2-23.

Table 2-23. Channel Bottom Sediment Monitoring and Screening Criteria for Metals

Station ID:	4ABWA008.53		Consensus-Based	
Collection Date Time:	04/02/2003 10:30		TEC	PEC
Name	Value	Comment Code	(mg/kg)	(mg/kg)
ARSENIC IN BOTTOM DEPOSITS (MG/KG AS AS DRY WGT)	5	U	9.79	33
BERYLLIUM IN BOTTOM DEPOSITS(MG/KG AS BE DRY WGT)	5	U		
CADMIUM,TOTAL IN BOTTOM DEPOSITS (MG/KG,DRY WGT)	1	U	0.99	4.98
CHROMIUM,TOTAL IN BOTTOM DEPOSITS (MG/KG,DRY WGT)	22.7		43.4	111
COPPER IN BOTTOM DEPOSITS (MG/KG AS CU DRY WGT)	9.6		31.6	149
LEAD IN BOTTOM DEPOSITS (MG/KG AS PB DRY WGT)	9.7		35.8	128
MANGANESE IN BOTTOM DEPOSITS (MG/KG AS MN DRY WGT)	315			
NICKEL, TOTAL IN BOTTOM DEPOSITS (MG/KG,DRY WGT)	6.5		22.7	48.6
SILVER IN BOTTOM DEPOSITS (MG/KG AS AG DRY WGT)	1	U		
ZINC IN BOTTOM DEPOSITS (MG/KG AS ZN DRY WGT)	35.9		121	459
ANTIMONY IN BOTTOM DEPOSITS (MG/KG AS SB DRY WGT)	5	U		
ALUMINUM IN BOTTOM DEPOSITS (MG/KG AS AL DRY WGT)	7,360			
SELENIUM IN BOTTOM DEPOSITS (MG/KG AS SE DRY WGT)	1	U		
IRON IN BOTTOM DEPOSITS (MG/KG AS FE DRY WGT)	15,500			
THALLIUM DRY WGTBOTMG/KG	5	U		
MERCURY,TOT IN BOT DEPOS (MG/KG AS HG DRY WGT)	0.1	U	0.18	1.06

U = parameter analyzed, but not detected.
TEC = Threshold effects concentration
PEC = Probable effects concentration

(shaded) - Minimum detection limit.

One sample analyzed for dissolved metals was taken on the same day as the sediment metals sample. These results are shown in Table 2-24. No samples exceeded any of the applicable aquatic life, human health, or EPA nationally recommended freshwater criteria.

Heavy metals such as mercury, chromium, cadmium, arsenic and lead in streams and rivers can damage aquatic insects at low concentrations. The metals tend to accumulate in the gills and muscles of aquatic organisms. Dissolved metals have been identified as important predictors of stream health. In the context of water quality criteria, dissolved metals are typically treated independently; however there is strong evidence that metals have a cumulative effect (Clements et al., 2000). The Cumulative Criterion Units (CCU) metals index accounts for this additive effect by standardizing each dissolved metal's concentration. The metals are summed together and the result is the CCU Metals Index score. When the CCU Metals Index is above 2, the cumulative effect is considered likely to harm aquatic life (Clements et al., 2000). The CCU score for this set of dissolved metals sample was 0.28, well below the threshold of concern.

Table 2-24. Dissolved Metals Monitoring and Screening Criteria

Station ID:	4ABWA008.53		AQUATIC LIFE		HUMAN HEALTH		EPA FRESHWATER	
Collection Date Time:	04/02/2003 10:30		FRESHWATER		Public	All Other	acute	chronic
Name	Value	Comment Code	Acute	Chronic	Water Supply	Surface Waters	CMC	CCC
	All units in µg/L, except for observed mercury (ng/L).							
CALCIUM, DISSOLVED (MG/L AS CA)	7.1							
MAGNESIUM, DISSOLVED (MG/L AS MG)	2.4							
ARSENIC, DISSOLVED (UG/L AS AS)	0.12		340	150	10	0	0	0
CADMIUM, DISSOLVED (UG/L AS CD)	0.1	U	3.9	1.1	5	0	2	0.25
CHROMIUM, DISSOLVED (UG/L AS CR)	0.71		570	10				
COPPER, DISSOLVED (UG/L AS CU)	0.56		13	9	1300	0	13	9
IRON, DISSOLVED (UG/L AS FE)	177				300		0	1000
LEAD, DISSOLVED (UG/L AS PB)	0.1		120	14	15	0	65	2.5
MANGANESE, DISSOLVED (UG/L AS MN)	45			0	50	0	0	0
THALLIUM, DISSOLVED (UG/L AS TL)	0.2	U			0.24	0.47	0	0
NICKEL, DISSOLVED (UG/L AS NI)	0.59		180	20	610	4600	470	52
SILVER, DISSOLVED (UG/L AS AG)	0.1	U	3.4	NA			0	0
ZINC, DISSOLVED (UG/L AS ZN)	1.62		120	120	7400	26000	120	120
ANTIMONY, DISSOLVED (UG/L AS SB)	0.1	U			5.6	640	0	0
MERCURY-TL,FILTERED WATER,ULTRATRACE METHOD NG/L	5.93		1.4	0.77	0	0	0	0

U = parameter analyzed, but not detected.
CMC = criteria maximum concentration (acute criterion)
CCC = criterion continuous concentration (chronic criterion)

(shaded) - Minimum detection limit.

DEQ uses its Probabilistic Monitoring Program to pilot innovative sampling techniques. During 2003, semi-permeable membrane devices (SPMD), or "virtual fish" were deployed for a minimum of 30 days at 41 randomly located stations across the state. SPMDs mimic the uptake of organic compounds into fish tissue by utilizing a synthetic fish oil inside a porous membrane. Station 4ABWA008.53 was one of the 41 randomly selected stations for SPMD deployment. The results of the analysis of the membrane are shown in Table 2-25. Note that the measured SPMD units and the WQS units are not directly comparable. The WQS are cited to show a relative magnitude of the various compounds, and the comments on the far right indicate the relative magnitude of the SPMD measured values relative to other SPMD measurements made in the state.

Table 2-25. Organic Compounds Detected with the Semi-Permeable Membrane Device (SPMD) at Station 4ABWA008.53

SPMD Parameter	Sample Date 04/02/03	Aquatic Life[1] Freshwater Acute	Aquatic Life[1] Freshwater Chronic	Human Health[1] Water Supply	Human Health[1] All other surface waters	Notes
	(ng/L)	(ng/L)				
a-Benzenehexachloride	32					
Acenaphthene	569			670,000	990,000	
Acenaphthylene	201					
Anthracene	78			8,300,000	40,000,000	
b-Benzenehexachloride	54					
Benz[a]anthracene	78			38	180	
Benzo[a]pyrene	65			38	180	
Benzo[b]fluoranthene	413			38	180	
Benzo[g,h,i]perylene	269					
Benzo[k]fluoranthene	176			38	180	
Chlordane	538	2400	4.3	8	8.1	
Chlorpyrifos	23	83	41			
Chrysene	1,378			3.8	18	
cis-Chlordane	174					
cis-Nonachlor	42					
Dacthal	56					
d-Benzenehexachloride	2					
DDD	58			3.1	3.1	
DDE	34			2.2	2.2	
DDT	57	1100	1	2.2	2.2	
Diazinon	1,493	170	170			
Dibenz[a,h]anthracene	85			38	180	
Dieldrin	237	240	56	0.52	0.54	
Endosulfan	1			62,000	89,000	
Endrin	25	86	36	59	60	
Fluoranthene	5,883			130,000	140,000	Highest in all 41 monitored sites.
Fluorene	770			1,100,000	5,300,000	
Heptachlor Epoxide	102	520	3.8	0.39	0.39	
Heptachlor	2	520	3.8	0.79	0.79	
Hexachlorobenzene	40			2.8	2.9	
Indeno[1,2,3-c,d]pyrene	67			38	180	
Lindane	56					
Methoxychlor	1		30	100,000		
Mirex	2		zero			
Naphthalene	4,019					
o,p'-DDD	34					
o,p'-DDE	17					
o,p'-DDT	21					
Oxychlordane	51					
PAH high	9,808					
PAH low	8,350					
PAHs	18,158					Twice as high as the highest value out of 41 monitored sites.
Pentachloroanisole	354					2nd highest in 41 monitored sites in Virginia.
Phenanthrene	2,791					3rd highest in 41 monitored sites.
p,p'-DDD	24					
p,p'-DDE	17					
p,p'-DDT	36					
Pyrene	2,771			830,000	4,000,000	3rd highest in 41 monitored sites
Total PCBs	206		14	0.64	0.64	
trans-Chlordane	89					
trans-Nonachlor	78					
Trifluralin	21					

[1] Virginia Water Quality Standards, 9 VAC25-260, January 2011 (converted from µg/L to ng/L by multipying by 1000).

Criteria exceeded by one or both samples.

2.9.3. DEQ – Other Relevant Monitoring or Reports

Relative Bed Stability (RBS) Analysis

A Log Relative Bank Stability (LRBS) test is a type of siltation index. An LRBS score of negative one (-1) indicates that sediments ten times larger than the median are moving at bankfull, with a medium probability of impairment from sediment. A high percentage of fine sediment in streams would directly contribute to embeddedness, the filling of the interstitial spaces in the channel bottom. LRBS scores < -1 are considered sub-optimal, while scores > -0.5 are considered optimal. All four Little Otter River sub-watersheds have a relatively high percentage of mean embeddedness according to this test, although the percent of fine material varies considerably among them. The LRBS indicates sediment as a major source in the Upper Little Otter River (4ALOR014.75) and Wells Creek, while Johns Creek is less than optimal, and the Lower Little Otter River (4ALOR007.20) scoring in the optimal range, as shown in Table 2-26. The low LRBS score at the upstream site on the main channel in the Little Otter River is indicative of highly modified channels, while the higher score at the downstream site may indicate recovery and a fairly healthy reduced loading from fines. The low LRBS score at the upstream Buffalo Creek site (4ABWA008.53) is indicative of highly modified channels, while the downstream site, even though it also has a low LRBS score, shows recovery with a reduced degree of embeddedness and a reduced loading from fines.

Table 2-26. RBS Analysis Results

StationID	Date	Percent Sand	Percent Fines	Mean Embeddedness (%)	LRBS*
4AJHN000.01	10/16/08	50.5%	6.8%	55.4	-0.703
4ALOR007.20	10/23/07	64.4%	0.0%	56.2	-0.249
4ALOR014.75	10/16/08	75.0%	11.0%	58.0	-1.207
4AWEL000.59	09/19/05	37.1%	20.0%	54.2	-1.124
4ABWA002.00	07/09/12	2.9%	0.0%	36.0	0.924
4ABWA008.53	07/09/12	4.8%	50.5%	55.1	-0.844

* LRBS > -0.5 indicates a normal sediment load;
LRBS < -1.0 indicates excessive sediment load.

2.9.4. Permitted Point Sources

There are no general discharge permits for single-family homes in any of the Little Otter River or Buffalo Creek watersheds.

There is one municipal separate stormwater sewer system (MS-4) permit for the roads and facilities of the Virginia Department of Transportation (VA040115) in the upper Buffalo Creek watershed, extending from the Lynchburg urbanized area.

There are two VPDES permits, one general permit, 6 industrial stormwater general permits (ISWGP), and one integrated discharge permit for a concrete facility in the Little Otter River watersheds, while there is only one ISWGP in Buffalo Creek, as shown in Table 2-27.

Table 2-27. Permitted Discharges

Facility Name	Permit No	Permit Type	Water Body	Receiving Stream
Bedford City - Wastewater Treatment Plant	VA0022390	VPDES	VAW-L26R	Little Otter River
Bedford County Schools - Body Camp Elementary	VA0020818	VPDES	VAW-L26R	Wells Creek, UT
Bedford City - Water Treatment Plant	VAG640006	General	VAW-L26R	Little Otter River, UT
Bedford Ready Mix Concrete Company	VAG110014	Concrete	VAW-L26R	John's Creek UT
Sam Moore Furniture LLC	VAR050528	ISWGP	VAW-L26R	Johns Creek, UT
Hilltop Lumber Co Inc	VAR050544	ISWGP	VAW-L26R	Little Otter River, UT
Rubatex International LLC	VAR050733	ISWGP	VAW-L26R	Johns Creek
Bedford County - Sanitary Landfill	VAR051233	ISWGP	VAW-L26R	Bell Branch/UT Machine Branch
Bedford City - Hylton Site	VAR051369	ISWGP	VAW-L26R	Johns Creek
Central VA Pallet and Stake Co	VAR052107	ISWGP	VAW-L26R	Little Otter River, UT
New London Auto Parts Inc	VAR051801	ISWGP	VAW-L27R	Buffalo Creek UT

The two VPDES and one General Permit holders above are required to perform monthly monitoring and to meet average and/or maximum, concentration and/or quantity pollutant limits. Table 2-28 provides a summary of the permitted pollutants in each of these permits, their permitted limits, and a summary of their discharge monitoring report (DMR) discharges.

- Of the two permit exceedences noted for the Bedford City WWTP, both were minor with the Biological Oxygen Demand (BOD) exceedence occurring in 2007, and the zinc exceedence occurring in 2002.
- Of the permit exceedences listed for Body Camp Elementary:
  - Flow: 11/117 exceedences; 7 between Jul-05 and Nov-07; 5 since Jun-11.

- BOD5: the average concentration limit has been exceeded 6 times; once in 2001 and the rest since May-10; the maximum concentration limit has been exceeded three times all since May-10; the average daily quantity limit has been exceeded 3 times all since May-10; and maximum quantity limit has been exceeded once in Jul-11.
- TSS: 2 minor exceedences in 2001.
- Ammonia: 36/89 measurements exceed the concentration average, but only one sample has exceeded since Oct-09.

Table 2-28. Permit Limits and Monthly DMR Summary

Facility Name	Parameter Description	Permit Limits						Monthly DMR Values, Apr-00 to May-12			
		Quantity			Concentration			Quantity		Concentration	
		Units	Average	Maximum	Units	Average	Maximum	Average	Maximum	Average	Maximum
Bedford City - Wastewater Treatment Plant (VA0022390)	FLOW	MGD	2.0	NL		***	***	1.01	1.6		
	PH		***	***		***	9.0				
	BOD5	kg/day	52.8	79.2	mg/L	6.9	10.3	8.94	52.6	2.08	12.2
	TSS	kg/day	230	340	mg/L	30	45	11.45	55.9	2.43	7.6
	CL2, TOTAL FINAL		***	***	mg/L	0.0043	0.0051				
	FLOW, INFLUENT	MGD	NL	NL	MGD	***	***	0.93	1.3		
	ZINC, TOTAL RECOVERABLE		***	***	mg/L	59	59			33.54	68
	LEAD, TOTAL RECOVERABLE		***	***	mg/L	6.8	6.8			0.46	6.4
	AMMONIA, AS N JAN-MAY		***	***	mg/L	3.3	4.4			0.13	0.4
	AMMONIA, AS N JUN-DEC		***	***	mg/L	1.4	1.9			0.14	0.7
	TOXICITY, FINAL, CHRONIC		***	***	mg/L	***	3.2				
	COPPER, DISSOLVED (UG/L AS CU)		***	***	µg/L	NL	NL			8.12	10
	E.COLI, > 1 SAMPLE/MONTH		***	***	cfu/100 mL	126	***			1.85	8.5
Bedford County Schools - Body Camp Elementary (VA0020818)	FLOW	MGD	0.0045	NL		***	***	0.003	0.0096		
	PH		***	***		***	9.0				
	BOD5	kg/day	400	600	mg/L	24	36	52.60	1716	11.66	83
	TSS	kg/day	500	800	mg/L	30	45	30.76	552	7.92	39.3
	CL2, TOTAL		***	***	mg/L	9.4	11.3				
	AMMONIA, AS N	kg/day	***	***	mg/L	2.93	2.93	0.045	0.184	4.18	27.9
	E.COLI		***	***	cfu/100 mL	126	***			1.46	10
Bedford City - Water Treatment Plant (VAG640006)	FLOW	MGD	0.038	NL		***	***	0.031	0.043		
	TSS		***	***	mg/L	30	60			4.28	8

*** = Not applicable; NL = no limit set.

- Denotes one or more exceedence of permit limits.

Between January 2008 and June 2012, there have been 29 land disturbing (construction stormwater) permits issued in the encompassing Little Otter River watershed representing a total disturbed acreage of 35.60 acres. Of those permits, 6 are current, comprising a total of 3.25 acres. Additional local construction permits for areas < 5 acres in size may also exist for single family construction and other small-scale construction.

During the same time period, there have been 10 land disturbing (construction stormwater) permits issued in the Buffalo Creek watershed representing a total disturbed acreage of 17.04 acres. Of those permits, 4 are current, comprising a total of

8.34 acres. Since 2010, Campbell County reports local construction permits in their portion of Buffalo Creek totaling 35.13 acres of disturbed land, of which 23.3 acres were for single family construction and the rest for commercial construction.

2.9.5. VAHWQP Household Drinking Water Analyses

The Virginia Household Water Quality Program (VAHWQP) conducted Drinking Water clinics in Appomattox and Campbell counties in May-June 2009, and in Bedford County in June-July 2009, where homeowners brought in well or spring water samples and/or tap water samples for water quality testing and analysis, shown in Table 2-29. These samples can be considered to be representative of the broader background groundwater quality in the area.

Table 2-29. VAHWQP County Drinking Water Clinic Results

		Appomattox and Campbell Counties, 2009 (n=30); Benham et al., 2010a.			Bedford County, 2009 (n=34); Benham et al., 2010b.		
Test	**Standard**	**Average**	**Max/ Extreme**	**% Exceeding Guidelines***	**Average**	**Max/ Extreme**	**% Exceeding Guidelines***
Iron (mg/L)	0.3	0.037	0.47	3.3	0.009	0.064	0
Manganese (mg/L)	0.05	0.033	0.525	10	0.018	0.165	11.8
Hardness (mg/L)	180	35.1	141	0	54.2	202.2	2.9
Sulfate (mg/L)	250	2.3	11.8	0	5.8	87.1	0
Chloride (mg/L)	250	2	8	0	3	12	0
Fluoride (mg/L)	2.0/4.0	0.2	0.4	0	0.25	1.6	0
Total Dissolved Solids (mg/L)	500	59	198	0	92	288	0
pH	6.5 to 8.5	7.69	5.5/7.7	53.3 (<6.5)	7.17	8	11.8 (< 6.5)
Copper (mg/L)	1.0/1.3	0.035	0.282	0	0.032	0.19	0
Sodium (mg/L)	20	5.08	12.28	0	9.67	44.03	11.8
Nitrate-N (mg/L)	10	4.374	29.1	6.7	3.854	26.4	11.8
Total Coliform Bacteria	Absent	–	–	66.7	–	–	52.9
E. coli Bacteria	Absent	–	–	10	–	–	2.9

* Guidelines are based on EPA standards for raw/tap water.

2.9.6. Big Otter River Bacteria TMDL and Implementation Plan

The bacteria impairments in Big Otter River and its tributaries, which include all of the Little Otter River sub-watersheds, were already addressed by the TMDL developed in 2000 (Mostaghimi et al., 2000) and the Implementation Plan in 2006 (Benham et al., 2006). Any reductions required by this TMDL developed for the benthic impairment will be coordinated with those called for by the bacteria TMDL and IP.

2.9.7. Recent Implementation of Best Management Practices (BMPs)

Little Otter River

Peaks of Otter SWCD reported implementation of livestock exclusion along 31.9 miles of stream in the Little Otter River watershed. This implementation was funded under a §319 Grant for the Big Otter River Implementation Plan conducted between July 2006 and June 2011. Of that total, 10.8 miles was along streams in the Upper Little Otter River, 17.8 miles along streams in the Lower Little Otter River, 3.3 miles along Wells Creek, and none along Johns Creek.

In September 2009, the City of Bedford WasteWater Treatment Division received a grant from the Virginia Clean Water Revolving Loan Fund Program, which was administered by DEQ, to install piping and equipment to be able to re-use the effluent, for non-contact use, from the WasteWater plant to Brooks Food Group. This project reduced the amount of potable water used at Brooks Food Group and also reduced the amount of process water used at the WasteWater plant. Construction was completed for this project in May 2010. After completion, the amount of potable water used reduced by 0.5 million gallons per month. In February 2011, the City of Bedford and Anderson & Associates, Inc. received the 2011 Engineering Excellence Honor Award for the Bedford Reclaimed Water Management Project given by ACEC Virginia (Bedford, Virginia Online).

DEQ has reported various actions taken to remediate identified sources of groundwater pollution in the watershed. Through the Bedford County Source Water Protection (SWP) program, an unlined landfill and associated seepage areas were found to be contributing volatile organic compounds (VOCs) to surface waters, and have been fenced off to allow volatilization, photo-degradation, and dilution, and to prevent access by livestock. A second older landfill in Bedford City had also been the source historically of many VOC exceedences of groundwater protection standards, and has been addressed with a seep collection and treatment system (SCTS) which captures seep water and transfers it to the WWTP for treatment. The SCTS captures between 350,000 and 500,000 gallons of seepage per month. Although VOCs are still detected below the landfill in Johns Creek, their concentrations are below groundwater standards (Gilmer, personal communication).

Buffalo Creek

Campbell County reported a total of 29 post-construction BMPs installed in the urban areas of its portion of the Buffalo Creek watershed between 2010 and the present, amounting to 5 extended detention ponds, 3 infiltration BMPs, 18 detention ponds, and 3 bio-retention installations.

Virginia Department of Forestry (VDOF) reported approximately 130 logging jobs in the Buffalo Creek watershed between 2009 and the present. Individual jobs varied in size from 1 to 100 acres.

The following BMPs have been reported in DCR's Agricultural Cost-share Database in each county portion:

Table 2-30. Agricultural BMPs in Bedford County portion of Buffalo Creek Watershed

BMP Code	BMP Name	Installed Units	Program Year				Grand Total
			2004	2007	2009	2010	
CP-22	Riparian Buffer Rent	Acres	3.9				3.9
CRFR-3	CREP Riparian Forest Buffer Planting	Acres	3.9				3.9
RB-4	Septic Tank System Replacement	Count			3	1	4
SL-6	Stream Exclusion With Grazing Land Management	Lin. Feet		50			50
SL-8H	Harvestable Cover Crop	Acres			35.8		35.8

Table 2-31. Agricultural BMPs in Campbell County portion of Buffalo Creek Watershed

BMP Code	BMP Name	Installed Units	Program Year					Grand Total
			2007	2008	2009	2010	2011	
RB-2	Connection to Public Sewer	Count	0	2	1	0	1	4
RB-3	Septic Tank System Repair	Count	0	0	2	1	0	3
RB-4	Septic Tank System Replacement	Count	0	1	0	2	0	3
RB-4P	Septic Tank System Installation/Replacement with I	Count	0	0	0	1	2	3
RB-5	Installation of Alternative Waste Treatment System	Count	0	1	0	0	1	2
SL-11	Permanent vegetative cover on critical areas	Acres	0	1	0	0	0	1
SL-6	Stream Exclusion With Grazing Land Management	Lin. Feet	661	0	0	0	0	661
SL-8H	Harvestable Cover Crop	Acres	0	0	0	0	108	108

2.9.8. Lynchburg College Studies on Timber Lake

Kate Skaggs conducted her senior research thesis on Timber Lake (2006) which provided some baseline water quality data for its contributing watershed. She notes that the original dam for the lake was breached in 1995, with the lake subsequently dredged and the dam rebuilt. In 1999, Timber Lake's watershed was established as a Watershed Improvement District (WID) with the power to tax residents, though that power has not yet been exercised. Three streams are tributary to Timber Lake: Buffalo Creek, Waterlick Creek, and Brown Creek. She noted that all three streams are somewhat impacted by urban development, but currently are in overall good health for urban streams. Timber Lake itself was assessed as being mesotrophic. High phosphorus levels are currently held in check by large numbers of Daphnia zooplankton, preventing excessive algal blooms. She notes, however, that increased loading from the tributaries due to increased development could rapidly shift that balance.

Data were collected for THA by Lynchburg College over an unspecified period of time. Calculations from spreadsheet data attributed to Ashley Palmer at Lynchburg College from 2010, quantified the net consumption and/or storage of phosphorus within Timber Lake on six monthly samples from June – November, although units could not be verified.

2.9.9. Citizen Monitoring Data from Timberlake Homeowner's Association (THA)

Monthly ambient water quality data has been collected at 11 points around Timber Lake and its tributary streams by THA from January-July 2006 and from March-September 2007. The THA data have been certified as level III data by DEQ. The location of the monitoring sites are shown in Figure 2-47, while graphs of the 9 physical, chemical and bacteria parameters are presented in Figures 2-48 through 2-56.

A professional lake monitoring service from Mechanicsville was contracted for data collection and analysis in 2012, but the data results are not currently available.

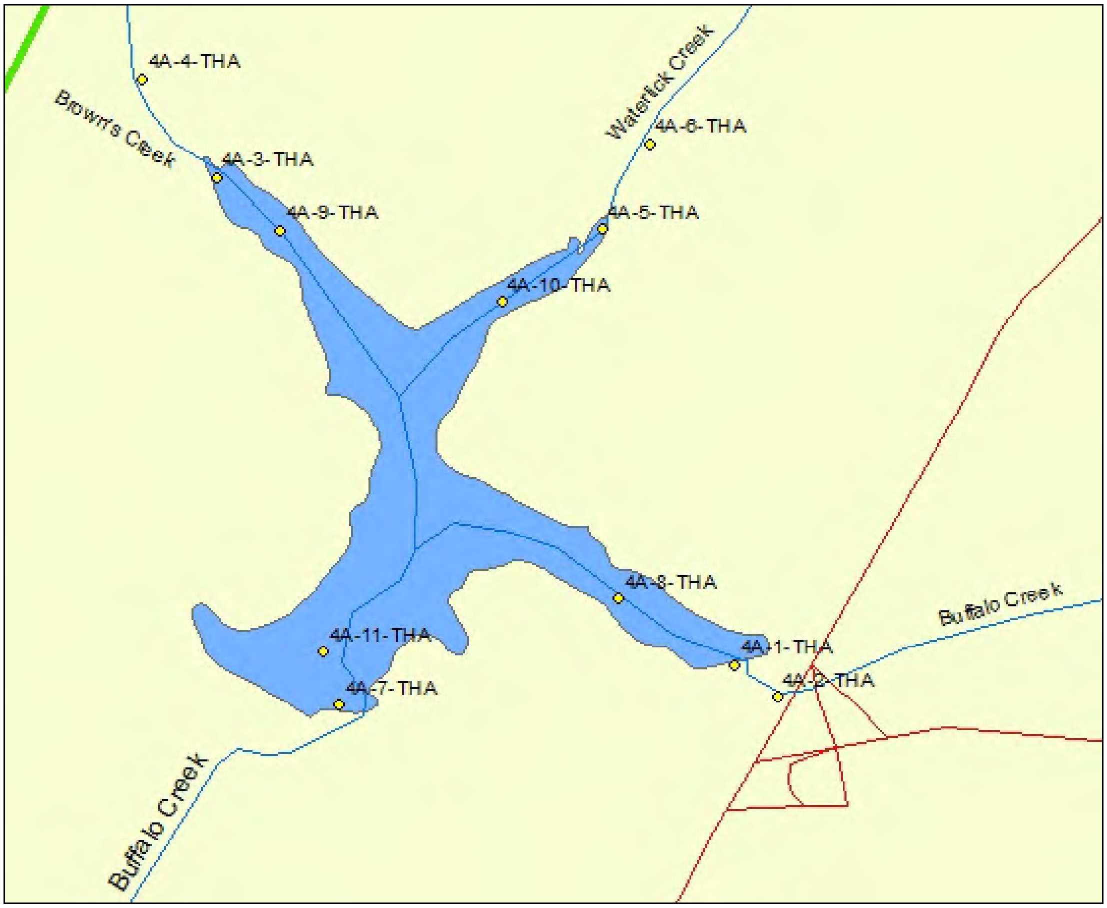


Figure 2-47. Location of THA Monitoring Sites on Timber Lake

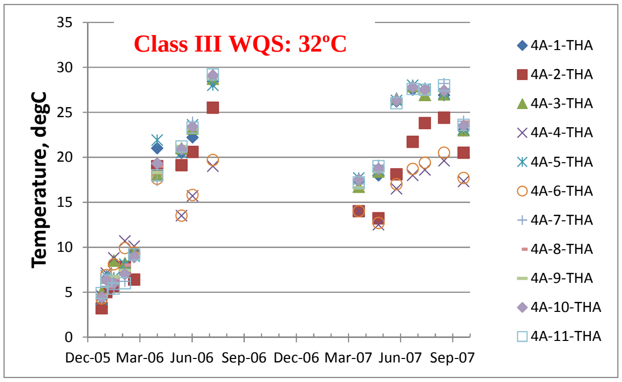


Figure 2-48. THA temperature

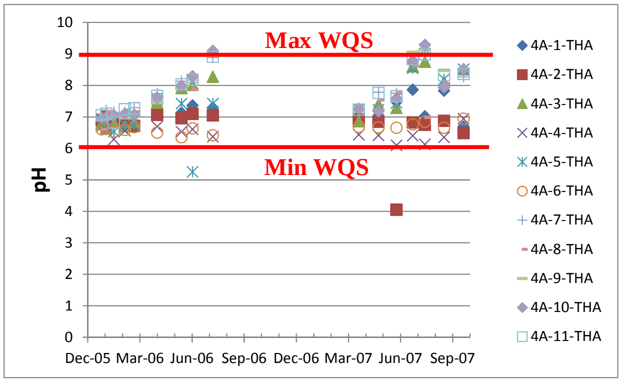


Figure 2-49. THA pH

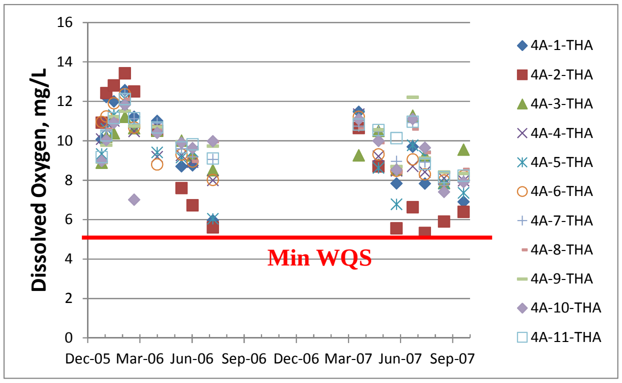


Figure 2-50. THA dissolved oxygen

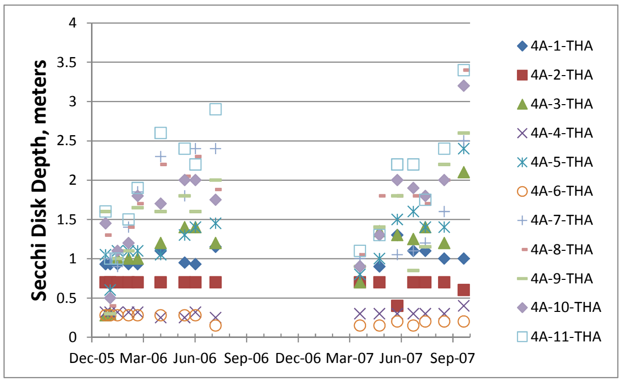


Figure 2-51. THA Secchi disk depth

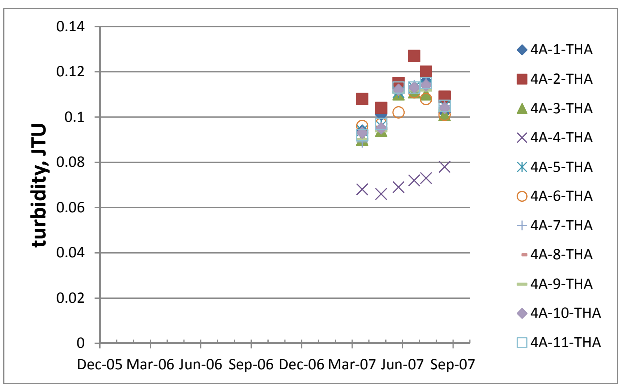


Figure 2-52. THA turbidity

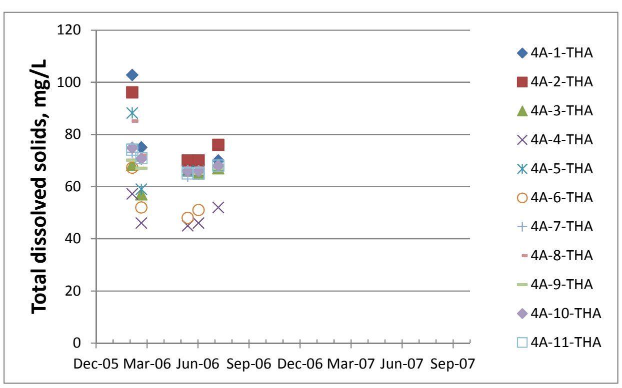


Figure 2-53. THA total dissolved solids

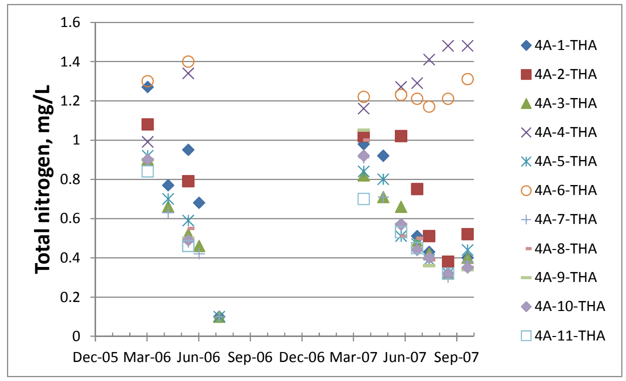


Figure 2-54. THA total nitrogen

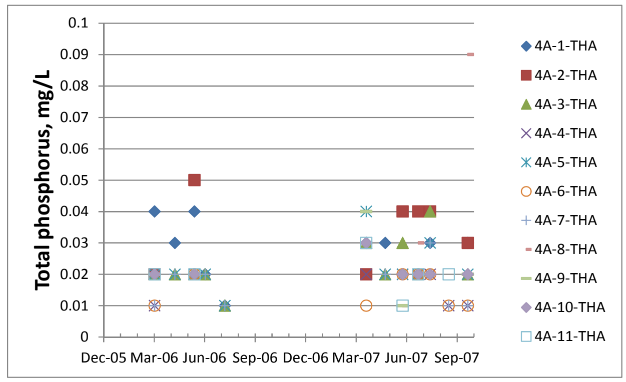


Figure 2-55. THA total phosphorus

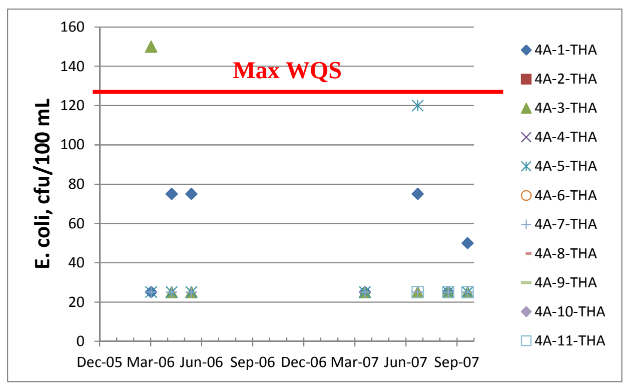


Figure 2-56. THA *Escherichia coli*

Chapter 3: BENTHIC STRESSOR ANALYSIS

3.1. Introduction

TMDLs must be developed for a specific pollutant. Since a benthic impairment is based on a biological inventory, rather than on a physical or chemical water quality parameter, the pollutant is not explicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in USEPA's Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for the impaired watershed in this study. A list of candidate causes was developed from the listing information, biological data, published literature, and stakeholder input. Chemical and physical monitoring data from DEQ provided additional evidence to support or eliminate the potential candidate causes. Biological metrics and habitat evaluations in aggregate provided the basis for the initial impairment listing, but individual metrics were also used to look for links with specific stressors, where possible. Volunteer monitoring data, land use distribution, Virginia Base Mapping Project (VBMP) aerial imagery, and visual assessment of conditions in and along the stream corridor provided additional information to investigate specific potential stressors. Logical pathways were explored between observed effects in the benthic community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause. The candidate benthic stressors considered in the following sections are ammonia, hydrologic modifications, nutrients, organic matter, pH, sediment, TDS/conductivity/sulfates, temperature, and toxics. The information in this section is adapted from the Stressor Analyses presented at the October 18, 2012 TAC meeting and from the revised stressor analysis reports for Little Otter River and Buffalo River dated December 6, 2012.

3.2. Analysis of Stressors for Upper Little Otter River

The suspected sources of the benthic impairment in the Upper Little Otter River were listed as habitat impacts from sediment deposition in stream, eroded stream banks, and removal of vegetation in the riparian zone in the 2010 list of impaired waters. A 5.71 mile segment above station 4ALOR014.75 was listed in 2002, and extended an additional 7.29 miles to its headwaters in 2008 for a total impaired segment length of 13.0 miles. The primary DEQ monitoring station for both ambient and biological monitoring is 4ALOR014.75, with an additional upstream ambient station (4ALOR021.92). The stressor may be something that either directly affected the benthic community or indirectly affected its habitat. Virginia SCI ratings suggest that the benthic community has alternated between being stressed and having a healthy community during the period from 1997 to 2012. Two consecutive samples between fall 2008 and summer 2011 were in the non-impaired range, but the most recent samples once again showed signs of stress.

A list of candidate stressors was developed and evaluated for the Upper Little Otter River in order to determine the pollutant(s) responsible for the benthic impairment. The available data were then analyzed for relationships or conditions that may show associations between potential stressors and changes in the benthic community. Depending on the strength of available evidence, the potential stressors were "eliminated", considered as "possible" stressors, or recommended as the "most probable" stressor. Candidate stressors included ammonia, pH, temperature, metals, toxic sediment organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength. The evaluation of each candidate stressor is discussed in the following sections.

3.2.1. Eliminated Stressors

Ammonia

High values of ammonia are toxic to many fish species and may affect the benthic community as well. Although there were only a few samples taken at the DEQ ambient monitoring site, all ammonia concentrations were close to or below the minimum detection limit. There was only one minor upstream point source and no reported fish kills that might point to ammonia as a possible stressor. Therefore ammonia was eliminated from further consideration as a stressor for Upper Little Otter River.

pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to live and grow. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge and urban runoff can potentially alter in-stream levels of pH. Although 11.8% of samples reported low pH exceedences in 2010 county-wide drinking water samples from Bedford County, no in-stream pH exceedences have been reported at the DEQ monitoring station since monitoring began in 1992. Therefore, pH was eliminated from further consideration as a stressor.

Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. The Upper Little Otter River is classified as a Class III Nontidal Waters, Coastal and Piedmont Zones stream, with a maximum temperature standard of 32°C. No exceedences of the temperature standard were recorded either DEQ ambient monitoring station. Therefore, no evidence supported temperature as a stressor, and it was eliminated.

Metals

Increased metals concentrations lead to low diversity and low total abundance of benthic organisms, with specific reduced abundance of metal-sensitive mayfly larvae and increased abundance of metal-tolerant midge larvae, or Chironomids (Clements, 1994). Only one metal (zinc) in one of nine channel bottom sediment samples exceeded its known consensus-based PEC. That occurred in 1993, and all six samples since then were at least an order of magnitude smaller and not exceeding. Most metals were below their MDLs. Only one of the dissolved metals (manganese) in the one of the nine samples exceeded its human health water supply criterion. That occurred in 2002, and the two samples since then have not exceeded the criterion. The cumulative metals index was well below the threshold for all samples. Therefore, since the historic minor exceedences of EPA aquatic life criteria or consensus-based PEC's no longer occur and no samples reported low total numbers of organisms, metals were eliminated from further consideration as a possible stressor.

Toxic Sediment Organic Compounds

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedences of freshwater aquatic life criteria or consensus-based Probable Effect Concentrations (PEC) for metals or inorganic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources. There have also been no reports of fish kills. No samples were deficient in total numbers of organisms, although the % shredder population was occasionally very low. None of the eleven sediment organic compounds tested for were above minimum detection levels in any of the nine channel bottom sediment samples. Therefore, toxic sediment organic compounds have been eliminated as a possible stressor.

Ionic Strength

Total dissolved solids (TDS) are the inorganic salts, organic matter and other dissolved materials in water. Elevated levels of TDS cause osmotic stress and alter the osmoregulatory functions of organisms (McCulloch et al., 1993). All specific conductivity measurements at the DEQ monitoring station on Upper Little Otter River were below the DEQ reference screening value of 500 µmhos/cm, and with the exception of two elevated values in 2011-2012, all were relatively low, averaging 88.9 µmhos/cm, but on a slightly increasing trend over time. Therefore, there was no evidence to support ionic strength as a possible cause of the benthic impairment, and it was eliminated.

3.2.2. Possible Stressors

Nutrients

Excessive nutrient inputs can lead to increasing algal growth, eutrophication, and low dissolved oxygen concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, dissolved oxygen levels may become low during overnight hours due to plant respiration. Sources of nitrogen include groundwater, residential wastewater, atmospheric deposition, and agricultural activities. Although high nitrate-N concentrations were reported in 11.8% of county-level household drinking water samples, 31 of DEQ's 53 total-N samples were in the "optimal" range used for selection of reference watersheds. In contrast to nitrogen, 161 of 213 TP samples were in the sub-optimal range; 4 of 61 TP samples were reported as exceeding their "observed effects" threshold of 0.20 mg/L in 2002; 2 out of 53 samples were reported as exceeding in 2006; and 4 exceedences have been noted between 2008 and 2010. Several low riparian vegetation zone width metric scores indicate the potential for increased nutrient contributions from surface runoff, as all samples before 2008 were rated as poor or very poor. Although there have been no exceedences of the dissolved oxygen standard (with one minor exception in 1999), the higher TP concentrations may be contributing to the occasionally lower percentage of sensitive families present in the community. Therefore, while it is doubtful that nutrients are the dominant stressor, they are determined to be a possible cause.

Organic Matter

Excessive organic matter (OM) can lead to low in-stream dissolved oxygen concentrations, which may adversely affect the survival and growth of benthic macro-invertebrates. Potential sources of organic matter in the Upper Little Otter River include household wastewater discharges, livestock access to streams, runoff from manured agricultural areas, and runoff from impervious areas. The Modified Family Biotic Index (MFBI) is one of the metrics incorporated in the VSCI that is a good indicator of organic pollution, with higher values related to poorer metric scores. All pre-1997 MFBI values were high. Hydropsychidae organisms dominated in all samples. A moderate proportion (43%) was in the organic TKN form, although the TN concentrations were relatively low. Abundant livestock in the watershed are a readily available source of OM. Only one DO exceedence was reported in 1999. Organic enrichment is somewhat supported by the types of abundant benthic organisms found in many of the samples – Hydropsychidae – typical of organic-enriched sites, and the occasional low ratios of scrapers to filterer-collectors, indicative of abundant suspended organic matter used as a food source by the filterer-collectors. Even though there was only one historic exceedence of the DO standard, historic high MFBI metric scores and moderate levels of organic N support organic matter as a possible stressor.

3.2.3. Most Probable Stressors

The most probable stressor contributing to the minor impairment of the benthic community in the Upper Little Otter River is considered to be sediment based on the following summary of available evidence.

Streambed Sedimentation

Excessive sedimentation can impair benthic communities through loss of habitat. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macro-invertebrate habitat. Potential sources of sediment include residential runoff, forestry and agricultural runoffs, construction sites, in-stream disturbances, and livestock with stream access. Although there were a relatively healthy percentage of haptobenthos in all samples, habitat metric scores for bank stability and bank vegetative protection have been decreasing since fall 1999. Abundant disturbed acreage is visible due to construction and other clearing. The LRBS siltation index score was < -1, indicating excessive sediment in stream bottom and the habitat metric scores for riparian vegetative zone width has increased since Fall 2006. While there were no high non-filterable residue (TSS) concentrations reported at the DEQ ambient monitoring site for Upper Little Otter River, no samples were taken during runoff events when sediment is more likely to be transported. However, sediment is supported as the most probable stressor by the low LRBS index and the low habitat stream bank metric scores.

3.3. Analysis of Stressors for Johns Creek

The suspected sources of the benthic impairment in Johns Creek were listed as "urban and agricultural NPS pollution", flashy flows that "appear to cause severe erosion of the stream banks", and sediment resuspension from the high density urbanized area (City of Bedford) in the 2010 list of impaired waters. The entire 2.13 mile segment of Johns Creek was listed in 2002 and extends from its headwaters to its confluence with the Upper Little Otter River. The primary DEQ monitoring station for both ambient and biological monitoring is 4AJHN000.01. The stressor may be something that either directly affected the benthic community or indirectly affected its habitat. Virginia SCI ratings suggest that the benthic community had a fairly severe impairment, but has gradually improved during the period from 1997 to 2012.

A list of candidate stressors was developed and evaluated for Johns Creek in order to determine the pollutant(s) responsible for the benthic impairment. The available data were then analyzed for known relationships or conditions that may show associations between potential stressors and changes in the benthic community. Depending on the strength of available evidence, the potential stressors were "eliminated", considered as "possible" stressors, or recommended as the "most probable" stressor. Candidate stressors included ammonia, pH, temperature, metals, toxic sediment organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength. The evaluation of each candidate stressor is discussed in the following sections.

3.3.1. Eliminated Stressors

Ammonia

High values of ammonia are toxic to many fish species and may affect the benthic community as well. Although there were only a few samples taken at the DEQ ambient monitoring site, all ammonia concentrations were close to or below the minimum detection limit. There are no upstream point sources and no reported fish kills that might point to ammonia as a possible stressor. Therefore ammonia was eliminated from further consideration as a stressor for Johns Creek.

pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to live and grow. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge and urban runoff can potentially alter in-stream levels of pH. Although 11.8% of samples reported low pH exceedences in 2010 county-wide drinking water samples from Bedford County, no in-stream pH exceedences have been reported at the DEQ monitoring station since monitoring began in 2000. Therefore, pH was eliminated from further consideration as a stressor.

Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. Johns Creek is classified as a Class III Nontidal Waters, Coastal and Piedmont Zones stream with a maximum temperature standard of 32°C.

No exceedences of the temperature standard were recorded at the DEQ ambient monitoring station. Therefore, no evidence supported temperature as a stressor, and it was eliminated.

Metals

Increased metals concentrations lead to low diversity and low total abundance of benthic organisms, with specific reduced abundance of metal-sensitive mayflies and increased abundance of metal-tolerant chironomids (Clements, 1994). No metals exceeded their known consensus-based PEC in the one channel bottom sediment sample taken in 2005. Most metals were below their MDLs. None of the dissolved metals exceeded their aquatic life or human health water supply criteria. The cumulative metals index was well below the threshold for the dissolved metals sample. Although the three earliest samples reported low total numbers of organisms, since no significant metals were detected in either channel bottom sediments or dissolved in the water column, metals were eliminated from further consideration as a possible stressor.

Ionic Strength

Total dissolved solids (TDS) are the inorganic salts, organic matter and other dissolved materials in water. Elevated levels of TDS cause osmotic stress and alter the osmoregulatory functions of organisms (McCulloch et al., 1993). While there were very few samples taken, all specific conductivity measurements at the DEQ monitoring station on Johns Creek were below the DEQ reference screening value of 500 µmhos/cm, and all were relatively low, around 200 µmhos/cm. Therefore, there was no evidence to support ionic strength as a possible cause of the benthic impairment, and it was eliminated.

3.3.2. Possible Stressors

Nutrients

Excessive nutrient inputs can lead to increasing algal growth, eutrophication, and low dissolved oxygen concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, dissolved oxygen levels may become low during overnight hours due to plant respiration. Sources of nitrogen include groundwater, residential wastewater, atmospheric deposition, and agricultural activities. A high degree of dominance was shown by 1 or 2 families, including Hydropsychidae, in each sample prior to 2006. Low riparian vegetation zone width metric scores indicate the potential for increased nutrient contributions from surface runoff, as all samples since 1999 were rated as poor or very poor. Although high nitrate-N concentrations were reported in 11.8% of county-wide household drinking water samples in Bedford County, all four of DEQ's total-N samples were in the "optimal" range used for selection of reference watersheds. In contrast to nitrogen, 3 of 6 TP samples were in the sub-optimal range, although none exceeded the "observed effects" threshold of 0.20 mg/L. There was one minor exceedence of the dissolved oxygen standard (in 1999). Therefore, it is doubtful that nutrients are the dominant stressor, although elevated phosphorus, in particular, may be a possible cause of, or contributor to, the impairment.

Organic Matter

Excessive organic matter can lead to low in-stream dissolved oxygen concentrations, which may adversely affect the survival and growth of benthic macro-invertebrates. Potential sources of organic matter in the Johns Creek watershed include primarily household wastewater discharges and runoff from impervious areas. The Modified Family Biotic Index (MFBI) is one of the metrics incorporated in the VSCI that is a good indicator of organic pollution, with higher values related to poorer metric scores. All pre-2008 MFBI values were high. Hydropsychidae organisms dominated in all samples. Although a high proportion (76%) of the total nitrogen (TN) was in the organic TKN form, all TN concentrations were relatively low. Only one DO exceedence was reported in 1999. Organic enrichment is somewhat supported by the types of abundant benthic organisms found in many of the samples – Hydropsychidae and Chironomidae – typical of organic-enriched sites. Even though there was only one historic exceedence of the DO standard, historic high MFBI metric scores and high proportions of organic N support organic matter as a possible stressor.

Toxic Sediment Organic Compounds

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedences of freshwater aquatic life criteria or consensus-based Probable Effect Concentrations (PEC) for metals or inorganic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources. There have also been no reports of fish kills. Three samples prior to 2001 had lower total numbers of organisms than usual and the shredder and scraper populations were occasionally low. However, no sediment organic compounds were tested for in the one channel bottom sediment sample in 2008. A 2008 fish inventory showed the fish population to be abundant, so if toxic sediment organic compounds contributed to the original impairment, they appear to have cleared out of the system. Since it is unknown whether toxic organic compounds contributed to the earlier impairment, they are listed as a possible stressor.

3.3.3. Most Probable Stressor

The most probable stressor contributing to the minor impairment of the benthic community in Johns Creek is considered to be sediment based on the following summary of available evidence.

Streambed Sedimentation

Excessive sedimentation can impair benthic communities through loss of habitat. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macro-invertebrate habitat. Potential sources of sediment include urban and residential runoff, construction sites, and in-stream disturbances. There were a relatively healthy percentage of haptobenthos in all samples. While there were no high non-filterable residue (TSS) concentrations in the few samples reported at the DEQ ambient monitoring site for Johns Creek, no samples were taken during runoff events when sediment is more likely to be transported. However, habitat metric scores for bank stability, bank vegetative protection, and sediment deposition have been consistently poor through sporadic sampling throughout the 1997-2012 sampling period; abundant disturbed acreage is visible due to construction and other clearing; and the LRBS siltation index score was -0.7, which indicates moderately excessive sediment from anthropogenic sources in the stream bottom. Therefore, sediment is supported as the most probable stressor based on the consistently poor habitat sediment metrics, consistent with the DEQ biologist observations of severe bank erosion, which may not show as strong a signal in the LRBS calculation, but still is due to anthropogenic activities through increased urban flows.

3.4. Analysis of Stressors for Wells Creek

The suspected sources of the benthic impairment in Wells Creek were listed as narrow riparian buffer zones and stream bank erosion, which contribute to deposition of fine sediment in the stream in the 2010 list of impaired waters. The entire 3.78 mile segment from its headwaters to its confluence with Machine Creek was listed initially in 2008. The initial DEQ biological sampling was performed in 2005 at station 4AWEL000.59 for the initial biological impairment listing in 2010. More recent (since 2011) biological monitoring has occurred at an upstream ambient station (4AWEL001.14). The stressor may be something that either directly affected the benthic community or indirectly affected its habitat. Virginia SCI ratings suggest that the benthic community has a minor impairment and has alternated between being stressed and having a healthy community during 2005 and from 2011 to 2012. The three spring samples are all considered to be stressed, while one fall sample is borderline and the most recent fall sample was in the non-impaired range.

A list of candidate stressors was developed and evaluated for Wells Creek in order to determine the pollutant(s) responsible for the benthic impairment. The available data were then analyzed for known relationships or conditions that may show associations between potential stressors and changes in the benthic community. Depending on the strength of available evidence, the potential stressors were “eliminated”, considered as “possible” stressors, or recommended as the “most probable” stressor. Candidate stressors included ammonia, pH, temperature, metals, toxic sediment organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength. The evaluation of each candidate stressor is discussed in the following sections.

3.4.1. Eliminated Stressors

Ammonia

High values of ammonia are toxic to many fish species and may affect the benthic community as well. Although there were only a few samples taken at the DEQ ambient monitoring site, all ammonia concentrations were close to or below the minimum detection limit. There were no point sources in the watershed and no reported fish kills that might point to ammonia as a possible stressor. Therefore ammonia was eliminated from further consideration as a stressor for Wells Creek.

pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to live and grow. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge and urban runoff can potentially alter in-stream levels of pH. Although 11.8% of samples reported low pH exceedences in 2010 county-wide drinking water samples from Bedford County, no in-stream pH exceedences have been reported at the DEQ monitoring station since monitoring began in 2000. Therefore, pH was eliminated from further consideration as a stressor.

Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. Wells Creek is classified as a Class III Nontidal Waters, Coastal and Piedmont Zones stream with a maximum temperature standard of 32°C. No exceedences of the temperature standard were recorded at either DEQ monitoring station. Therefore, no evidence supported temperature as a stressor, and it was eliminated.

Metals

Increased metals concentrations lead to low diversity and low total abundance of benthic organisms, with specific reduced abundance of metal-sensitive mayflies and increased abundance of metal-tolerant chironomids (Clements, 1994). No metals exceeded their known consensus-based PEC in the one channel bottom sediment sample taken in 2008. Most metals were below their MDLs. None of the dissolved metals exceeded its aquatic life or human health water supply criteria. The cumulative metals index was well below the threshold for all samples. Therefore, since no samples reported low total numbers of organisms and metal concentrations were all minimal, metals were eliminated from further consideration as a possible stressor.

Toxic Sediment Organic Compounds

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedences of freshwater aquatic life criteria or consensus-based Probable Effect Concentrations (PEC) for metals or inorganic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources. There have also been no reports of fish kills. No samples were deficient in total numbers of organisms, although the shredder population was occasionally low. None of the eighteen sediment organic compounds tested in the one 2008 sample were above their minimum detection levels. Therefore, toxic sediment organic compounds have been eliminated as a possible stressor.

Ionic Strength

Total dissolved solids (TDS) are the inorganic salts, organic matter and other dissolved materials in water. Elevated levels of TDS cause osmotic stress and alter the osmoregulatory functions of organisms (McCulloch et al., 1993). All specific conductivity measurements at the DEQ monitoring station on Wells Creek were below the DEQ reference screening value of 500 µmhos/cm, and with the exception of one 2011 value of 326 µmhos/cm, all were relatively low, around 100 µmhos/cm. Therefore, there was no evidence to support ionic strength as a possible cause of the benthic impairment, and it was eliminated.

3.4.2. Possible Stressors

Nutrients

Excessive nutrient inputs can lead to increasing algal growth, eutrophication, and low dissolved oxygen concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, dissolved oxygen levels may become low during overnight hours due to plant respiration. Sources of nitrogen include groundwater, residential wastewater, atmospheric deposition, and agricultural activities. High nitrate-N concentrations were reported in 11.8% of county-level household drinking water samples, but only 1 of 8 TN samples in Wells Creek was rated sub-optimal. In contrast to nitrogen, 8 of 9 TP samples were in the sub-optimal range with one minor exceedence of its "observed effects" threshold of 0.20 mg/L reported in July 2011. Each sample was dominated by the hydropsychidae family. Although there have been no exceedences of the dissolved oxygen standard, the elevated TP concentrations may be contributing to the occasionally lower percentage of sensitive families present in the community. Therefore, while it is doubtful that nutrients are the dominant stressor, they are determined to be a possible cause.

Organic Matter

Excessive organic matter can lead to low in-stream dissolved oxygen concentrations, which may adversely affect the survival and growth of benthic macro-invertebrates. Potential sources of organic matter in Wells Creek include household wastewater discharges, livestock access to streams, runoff from manured agricultural areas, and runoff from impervious areas. The Modified Family Biotic Index (MFBI) is one of the metrics incorporated in the VSCI that is a good indicator of organic pollution, with higher values related to poorer metric scores. MFBI values from each of two samples at the downstream site in 2005 were high. Hydropsychidae organisms dominated in all samples. Abundant livestock in the watershed are a readily available source of OM. Organic enrichment is somewhat supported by the types of abundant benthic organisms found in many of the samples – Chironomidae and Hydropsychidae – typical of organic-enriched sites. Historic high MFBI metric scores are the primary evidence that support organic matter as a possible stressor.

3.4.3. Most Probable Stressors

The most probable stressor contributing to the impairment of the benthic community in Wells Creek is considered to be sediment based on the following summary of available evidence.

Streambed Sedimentation

Excessive sedimentation can impair benthic communities through loss of habitat. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macro-invertebrate habitat. Potential sources of sediment include residential runoff, forestry and agricultural runoffs, construction sites, in-stream disturbances, and livestock with stream access. There were a relatively healthy percentage of haptobenthos in all samples. While there were no high non-filterable residue (TSS) concentrations reported at the DEQ ambient monitoring site for Upper Little Otter River, no samples were taken during runoff events when sediment is more likely to be transported. Habitat metric scores for sediment deposition were poor in all samples. Abundant disturbed acreage is visible due to construction and other clearing. The LRBS siltation index score was < -1, indicating excessive sediment in stream bottom from anthropogenic sources. Therefore, sediment is supported as the most probable stressor by the low LRBS index and the poor habitat sediment metric scores.

3.5. Analysis of Stressors for Lower Little Otter River

The suspected sources of the benthic impairment in the Lower Little Otter River included influence of an upstream WWTP, habitat impacts due to embeddedness and stream bank erosion, and high phosphorus levels in the 2010 list of impaired waters. The 14.33 mile segment starting at the confluence of the Little Otter River and Johns Creek and extending downstream to its confluence with the Big Otter River was listed in 2010 based on biological assessments at three DEQ stations – 4ALOR012.20, 4ALOR008.64, and 4ALOR007.20, although a portion of the segment around station 4ALOR014.33, just downstream of the Little Otter River confluence with Johns Creek, was originally listed with a moderate impairment in 2002. The DEQ ambient monitoring stations along this segment include 4ALOR008.64, 4ALOR010.78, and 4ALOR014.33. The stressor may be something that either directly affected the benthic community or indirectly affected its habitat. The stressor may have been contributed directly to the stream, from the land draining directly to the impaired segment, or from upstream tributaries. Virginia SCI ratings suggest that the benthic community has a minor impairment with an improving trend since the mid-90s, with one sample in summer 2011 in the non-impaired range, though the most recent samples once again showed signs of stress.

A list of candidate stressors was developed and evaluated for the Lower Little Otter River in order to determine the pollutant(s) responsible for the benthic impairment. The available data were then analyzed for known relationships or conditions that may show associations between potential stressors and changes in the benthic community. Depending on the strength of available evidence, the potential stressors were "eliminated", considered as "possible" stressors, or recommended as the "most probable" stressor. Candidate stressors included ammonia, pH, temperature, metals, toxic sediment organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength. The evaluation of each candidate stressor is discussed in the following sections.

3.5.1. Eliminated Stressors

Ammonia

High values of ammonia are toxic to many fish species and may affect the benthic community as well. Although there were only a few samples taken at the DEQ ambient monitoring site, all ammonia concentrations were close to or below the minimum detection limit. There was a major upstream point source (WWTP) with very low average daily average ammonia concentrations and no reported fish kills that might point to ammonia as a possible stressor. Therefore ammonia was eliminated from further consideration as a stressor for the Lower Little Otter River.

pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to live and grow. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge and urban runoff can potentially alter in-stream levels of pH. Although 11.8% of samples reported low pH exceedences in 2010 county-wide drinking water samples from Bedford County, no in-stream pH exceedences were reported at any of the DEQ monitoring station since monitoring began in 1990. Therefore, pH was eliminated from further consideration as a stressor.

Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. The Lower Little Otter River is classified as a Class III

Nontidal Waters, Coastal and Piedmont Zones stream with a maximum temperature standard of 32°C. No exceedences of the temperature standard were recorded at any of the DEQ ambient monitoring stations. Therefore, no evidence supported temperature as a stressor, and it was eliminated.

Metals

Increased metals concentrations lead to low diversity and low total abundance of benthic organisms, with specific reduced abundance of metal-sensitive mayflies and increased abundance of metal-tolerant chironomids (Clements, 1994). No metals exceeded their known consensus-based PEC out of a total of 14 samples at 5 different stations along this stream segment. Most metals were below their MDLs. None of the dissolved metals exceeded its aquatic life or human health water supply criteria in either of the two water column samples, one in 2001 and another in 2007, at different stations. The cumulative metals index was well below the threshold for all samples. Therefore, since all water quality samples had negligible metals concentrations and no samples reporting low total numbers of organisms, metals were eliminated from further consideration as a possible stressor.

Toxic Sediment Organic Compounds

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedences of freshwater aquatic life criteria or consensus-based Probable Effect Concentrations (PEC) for metals or inorganic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources. Although three samples between 1997 and 2000 had smaller total numbers of organisms, there have also been no reports of fish kills, and abundant fish were inventoried in a 2007 sample. None of the eleven sediment organic compounds tested for were above minimum detection levels in any of the eleven channel bottom sediment samples taken at five different stations along the impaired segment between 1993 and 2007. Therefore, toxic sediment organic compounds have been eliminated as a possible stressor.

Ionic Strength

Total dissolved solids (TDS) are the inorganic salts, organic matter and other dissolved materials in water. Elevated levels of TDS cause osmotic stress and alter the osmoregulatory functions of organisms (McCulloch et al., 1993). All specific conductivity measurements at the DEQ monitoring station on Upper Little Otter River were below the DEQ reference screening value of 500 µmhos/cm, although these values increased considerably between stations 14.75 and station 14.33 due to effluent inputs from the WWTP at mile 14.36. However, conductivity values were still all relatively low, averaging 134 µmhos/cm over the period of record. Therefore, there was insufficient evidence to support ionic strength as a possible cause of the benthic impairment, and it was eliminated.

3.5.2. Possible Stressors

Organic Matter

Excessive organic matter can lead to low in-stream dissolved oxygen concentrations, which may adversely affect the survival and growth of benthic macro-invertebrates. Potential sources of organic matter in the Lower Little Otter River include household and municipal wastewater discharges, livestock access to streams, runoff from manured agricultural areas, and runoff from impervious areas. The Modified Family Biotic Index (MFBI) is one of the metrics incorporated in the VSCI that is a good indicator of organic pollution, with higher values related to poorer metric scores. All pre-1999 MFBI values were high. Hydropsychidae organisms dominated in all samples. A few Asellidae organisms were present in some samples. A moderate proportion of the TN (49%) was in the organic TKN form at the station just downstream from the WWTP. Abundant livestock in the watershed are a readily available source of OM. Only one DO exceedence was reported in 2002. Organic enrichment is somewhat supported by the types of abundant benthic organisms found in many of the samples – Hydropsychidae – typical of organic-enriched sites. Even though there was only one historical exceedence of the DO standard, historic high MFBI metric scores and moderate levels of organic N support organic matter as a possible stressor.

3.5.3. Most Probable Stressors

The most probable stressor contributing to the minor impairment of the benthic community in the Lower Little Otter River is considered to be nutrients based on the following summary of available evidence.

Nutrients

Excessive nutrient inputs can lead to increasing algal growth, eutrophication, and low dissolved oxygen concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, dissolved oxygen levels may become low during overnight hours due to plant respiration. Sources of nitrogen include groundwater, residential wastewater, atmospheric deposition, and agricultural activities. High nitrate-N concentrations were reported in 11.8% of county-level household drinking water samples, and 14 of DEQ's 25 samples at the uppermost station (14.33) were in the "sub-optimal" range used for selection of reference watersheds. In addition, approximately 50% of all TP samples at all three Lower LOR stations were reported as exceeding their "observed effects" threshold of 0.20 mg/L. Low riparian vegetation zone width metric scores indicate the potential for increased nutrient contributions from surface runoff, as all samples were rated as poor or marginal. Although there was only one minor exceedence of the dissolved oxygen standard, the higher TN and TP concentrations appear to be the most likely contributor to the occasionally lower percentage of sensitive taxa present in the community. Therefore, nutrients were determined to be one of the most probable stressor in the Lower Little Otter River.

Streambed Sedimentation

Excessive sedimentation can impair benthic communities through loss of habitat. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macro-invertebrate habitat. Potential sources of sediment include residential runoff, forestry and agricultural runoffs, construction sites, in-stream disturbances, and livestock with stream access. Additionally, abundant disturbed acreage is visible due to construction and other clearing. However, the LRBS siltation index score at the most downstream station (7.20) was -0.25, indicating a normal distribution and amount of sediment in the stream channel bottom. There were a relatively healthy percentage of haptobenthos in all samples, and the habitat metric scores for riparian vegetative zone width increased since Fall 2006. Nonetheless, habitat metric scores were consistently poor for bank stability and bank vegetative protection at the most upstream station (14.33) in this impaired segment, although scores were somewhat better at the downstream stations. There were some high non-filterable residue (TSS) concentrations reported at the DEQ ambient monitoring site prior to 2000 for Lower Little Otter River, though it is unknown whether or not these samples were taken during runoff events when sediment is more likely to be transported.

DEQ biologists provided the following additional comments on this stream segment which helped put the contrasting data in this stream reach in perspective. A portion of the 400m reach (used for the biological samples at station 4ALOR007.20) is in an area of the Little Otter River constrained by a steep hillside on the left downstream bank. In addition, the reach is found in a series of ox-bow bends of the river. The site appears to be "uncharacteristic of the Little Otter River especially in comparison to 4ALOR014.75." In addition, Dr. Larry Willis noted on the RBS field sheets that the reach is in a 'gorge.' It is expected that in this sinuous and constrained section of the Little Otter River that fine sediment and sand are moved through the reach and settle out in less constrained and less sinuous sections of the river, while in comparison, the sampling reach at 4ALOR014.75 lacks sinuosity.

The Relative Bed Stability (RBS) scores of the two sites (4ALOR007.20 and 4ALOR014.75) were -0.2485 and -1.2073, respectively. The initial TMDL Stressor Analysis accounted for the RBS values and did not yield sediment as the most probable stressor in the Lower Little Otter segment due to the higher RBS value and high nutrient values in the segment. The higher RBS value at 4ALOR007.20 indicates that sediment is less likely to be a stressor. However, the Percent Sand and Mean Embeddedness measurements are important sediment metrics to compare between the two sites. At 4ALOR007.20 and 4ALOR014.75, Percent Sand was 64% and 75%, and Mean Embeddedness was 74.9% and 89.6%, respectively. While there is a difference between the two sites when comparing these two measurements, the best professional judgment of the regional biologist was that both measurements' scores indicate a negative impact on the benthic community. In addition, measures of percent bedrock, percent boulder, and percent cobble were greater in the reach of 4ALOR007.20 vs. 4ALOR014.75 indicating that sediment and fines do not settle out in the 4ALOR007.20 reach as they do in the 4ALOR014.75 reach.

In summary, while the RBS score at 4ALOR007.20 indicates that sediment is less likely to be a stressor, the uncharacteristic constraining features and sinuosity at 4ALOR007.20 likely prevent much sediment from being deposited and observed. In contrast to the RBS score, a Mean Embeddedness value of 74.9% is detrimental enough to the benthic community to yield sediment as a co-stressor with nutrients. Based on the DEQ regional biologist's analysis, sediment was added as a co-stressor in the Lower Little Otter River.

3.6. Analysis of Stressors for Buffalo Creek

The suspected sources of the benthic impairment in Buffalo Creek were listed as "increased sedimentation" and "flashy flows causing erosion and nutrient enrichment" in the 2008 list of impaired waters. The primary DEQ monitoring station for both ambient and biological monitoring is 4ABWA008.53. The stressor may be something that either directly affected the benthic community or indirectly affected its habitat. The stressor may have been contributed directly to the stream, from the land draining directly to the impaired segment, or from upstream tributaries. Virginia SCI ratings suggest that the benthic community has been variably stressed at different times during the period from 2003 to 2012.

A list of candidate stressors was developed and evaluated for Buffalo Creek in order to determine the pollutant(s) responsible for the benthic impairment. A potential stressor checklist was used to evaluate known relationships or conditions that may show associations between potential stressors and changes in the benthic community. Depending on the strength of available evidence, the potential stressors were "eliminated", considered as "possible" stressors, or recommended as the "most probable" stressor. Candidate stressors included ammonia, pH, temperature, metals, toxic organic compounds, nutrients, organic matter, streambed sedimentation, and ionic strength. The evaluation of each candidate stressor is discussed in the following sections.

3.6.1. Eliminated Stressors

Ammonia

High values of ammonia are toxic to many fish species and may affect the benthic community as well. Even though ammonia was not monitored at the DEQ ambient monitoring site, there were no upstream point sources and no reported fish kills that might point to ammonia as a possible stressor. Therefore ammonia was eliminated from further consideration as a stressor for Buffalo Creek.

pH

Benthic macro-invertebrates require a specific pH range of 6.0 to 9.0 to live and grow. Changes in pH may adversely affect the survival of benthic macro-invertebrates. Treated wastewater, mining discharge and urban runoff can potentially alter in-stream levels of pH. Although two exceedences of the minimum pH standard were reported within Timber Lake, and high percentages of exceedences were reported in drinking water samples from both encompassing counties (53.3% in Appomattox/Campbell County and 11.8% in Bedford County), no in-stream pH exceedences have been reported at the DEQ monitoring station since monitoring began in 2003. Therefore, pH was eliminated from further consideration as a stressor.

Temperature

Elevated temperatures can stress benthic organisms and provide sub-optimal conditions for their survival. Buffalo Creek is classified as a Class III Nontidal Waters, Coastal and Piedmont Zones stream with a maximum temperature standard of 32°C. No exceedences of the temperature standard were recorded at any of the THA monitoring locations or at the DEQ ambient monitoring station. Therefore, no evidence supported temperature as a stressor, and it was eliminated.

Metals

Increased metals concentrations lead to low diversity and low total abundance of benthic organisms, with specific reduced abundance of metal-sensitive mayflies and increased abundance of metal-tolerant chironomids (Clements, 1994). None of metals concentrations in the one channel bottom sediment sample exceeded any known consensus-based PECs and many were below MDL; none of the dissolved metals concentrations in the one sample exceeded either aquatic like or human health criteria; and the cumulative metals index was well below the threshold. None of the biological samples had low organism counts. Therefore, metals were eliminated from further consideration as a possible stressor.

Nutrients

Excessive nutrient inputs can lead to increasing algal growth, eutrophication, and low dissolved oxygen concentrations that may adversely affect the survival of benthic macro-invertebrates. In particular, dissolved oxygen levels may become low during overnight hours due to plant respiration. Sources of nitrogen include groundwater, residential wastewater, atmospheric deposition, and agricultural activities. Several low riparian vegetation zone width metric scores could increase nutrient contributions from surface runoff, but none of these were before 2009. While high nitrate-N concentrations were reported in 6.7% and 11.8% of county-level household drinking water samples, 41 of DEQ's 44 total-N samples were in the "optimal" range used for selection of reference watersheds. No TP concentrations were reported in excess of Virginia's "threatened waters" 0.2 mg/L threshold, and 19 of DEQ's 44 total-P samples were in the "optimal" range, with only 4 samples in the "sub-optimal" range. Chironomidae and Hydropsychidae - organisms associated with excessive nutrients, dominate the benthic community in Buffalo Creek. Although the two dominant organisms comprise approximately 62% of each sample, there is a good diversity of organisms, with a fair number of sensitive families. Therefore, nutrients do not appear to be impacting the biological community in Buffalo Creek, and so were eliminated as a possible stressor.

Ionic Strength

Total dissolved solids (TDS) are the inorganic salts, organic matter and other dissolved materials in water. Elevated levels of TDS cause osmotic stress and alter the osmoregulatory functions of organisms (McCulloch et al., 1993). The TDS measurements reported for the eleven THA ambient monitoring sites around Timber Lake were mostly in the "optimal" range (< 100 mg/L), with no sample concentrations > 110 mg/L. All specific conductivity measurements at the DEQ monitoring station on Buffalo Creek were below the DEQ reference screening value of 500 µmhos/cm, and none were > 130 µmhos/cm. Therefore, there was no evidence to support ionic strength as a possible cause of the benthic impairment, and it was eliminated.

3.6.2. Possible Stressors

Toxic Sediment Organic Compounds

Toxic substances by definition are not well tolerated by living organisms. The presence of toxics as a stressor in a watershed may be supported by very low numbers of any type of organisms, low organism diversity, exceedences of freshwater aquatic life criteria or consensus-based Probable Effect Concentrations (PEC) for metals or inorganic compounds, by low percentages of the shredder population, reports of fish kills, or by the presence of available sources. While there are low percentages of shredders in many samples, there are abundant organisms, good diversity, and pollutant sensitive organisms represented in all samples, with the possible exception of the fall 2003 sample. There have been no reports of fish kills, and no exceedences of EPA aquatic life criteria or consensus-based PECs in the one channel bottom sediment sample. However, many compounds were detected at relatively high levels during the deployment of a semi-permeable membrane device, or "virtual fish", including fluoranthene, PAHs, phenanthrene, and pyrene. These compounds are indicative of urban runoff related to tar-based asphalt sealants. Therefore, toxic sediment organic compounds have been considered as a possible stressor.

Organic Matter

Excessive organic matter can lead to low in-stream dissolved oxygen concentrations, which may adversely affect the survival and growth of benthic macro-invertebrates. Potential sources of organic matter in Buffalo Creek include household wastewater discharges, livestock, and runoff from impervious areas. Organic enrichment is also supported by the types of abundant benthic organisms found in many of the samples – Hydropsychidae and Chironomidae – typical of organic-enriched sites. The Modified Family Biotic Index (MFBI) is one of the metrics incorporated in the VSCI that is a good indicator of organic pollution, with higher values related to poorer metric scores. The high MFBI metric scores in Buffalo Creek were the primary evidence in support of organic matter as a possible stressor.

3.6.3. Most Probable Stressors

The most probable stressor contributing to the impairment of the benthic community in Buffalo Creek is considered to be sediment based on the following summary of available evidence.

Streambed Sedimentation

Excessive sedimentation can impair benthic communities through loss of habitat. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macro-invertebrate habitat. Potential sources of sediment include residential runoff, forestry and agricultural runoffs, livestock access to streams, construction sites, and in-stream disturbances. While there were no high non-filterable residue (TSS) concentrations reported at the DEQ ambient monitoring site for Buffalo Creek or high turbidity measurements in and around Timber Lake by THA, no samples were taken during runoff events when sediment is more likely to be transported. There are livestock present in the watershed with stream access. There has been recent timber harvesting activity in the watershed, along with abundant disturbed acreage due to construction and other clearing particularly in the Timberlake area. In addition, two sets of measurements of relative bed stability were conducted near each of the two DEQ monitoring sites on Buffalo Creek. The upper site (4ABWA008.53) showed considerable impact with moderately excessive sedimentation and a high percentage of fines from anthropogenic sources, while the downstream station (4ABWA002.00) appeared to have little or no impact from anthropogenic sources. Therefore, sediment appears to be impacting the uppermost portion of the impaired Buffalo Creek segment and is supported as the most probable stressor by the low LRBS sedimentation index and the presence of many land-disturbing activities.

3.7. Stressor Analyses Summaries

The Upper Little Otter River (VAW-L26R_LOR04A00) stream segment is impaired, but on an overall increasing trend for its aquatic life use, with 2 out of 4 recent individual VSCI sample scores being in the “non-impaired” range. The Upper Little Otter River is impacted by a combination of urban and agricultural land uses. Sediment was selected as the most probable stressor based on the poor stream bank habitat scores and the evidence given by the LRBS analysis indicating excessive sediment contributions from anthropogenic sources.

The Johns Creek (VAW-L26R_JHN01A00) stream segment was severely impaired for its aquatic life use between 1997 and 2008, but has been gradually improving. Johns Creek is impacted by a combination of urban and agricultural land uses. Sediment was selected as the most probable stressor based on consistently poor habitat sediment metrics.

The Wells Creek (VAW-L26R_WEL01A02) stream segment shows impairment for its aquatic life use primarily in the spring samples, with the most recent individual VSCI fall sample score being in the "non-impaired" range. Wells Creek is impacted primarily by agricultural land uses. Sediment was selected as the most probable stressor based on the poor habitat sediment scores and the evidence given by the LRBS analysis indicating excessive sediment contributions from anthropogenic sources.

The Lower Little Otter River (VAW-L26R_LOR01A00, VAW-L26R_LOR02A00, VAW-L26R_LOR03A00) stream segments are impaired for their aquatic life use, with the degree of impairment decreasing over time and from upstream to downstream, although the most recent samples have once again shown signs of stress. The Lower Little Otter River is impacted primarily by the WWTP effluent discharges for nutrients, with sediment coming from a combination of upstream impaired segments, instream bank and channel erosion, and land disturbance in the immediate watershed. Although the WWTP is not monitoring for nutrients at this time, it is bracketed by DEQ monitoring stations within a half mile of each other, which show increased nutrient levels at the downstream station with no other plausible source of nutrients. Therefore, the most probable stressors in this segment are both nutrients and sediment, with nutrients primarily and apparently related to WWTP effluent discharge.

The Buffalo Creek (VAC-L27R_BWA01A00, VAC-L27R_BWA02A02) stream segment is impaired for its aquatic life use, primary in the upstream portion of the segment, with some recovery shown in the downstream segment, whose watershed is predominantly forested. Buffalo Creek is impacted by both urban/residential development and agricultural land uses. Sediment was selected as the most probable stressor based on the low upstream LRBS score, livestock with stream access, and the presence of many other land-disturbing activities.

In addition to the benthic impairments, these watersheds are part of the larger Big Otter River watershed, which also has a bacteria impairment addressed during a previously developed TMDL (Mostaghimi et al., 2000) and implementation plan (VT-BSE, 2006). Pollutant sources which were identified to affect the bacteria load reductions in the bacteria TMDL will also affect loads from stressors identified for the biological impairment. In particular, the bacteria TMDL calls for reductions of 85% from bacteria loads on cropland and pasture and 30% reduction from livestock with direct stream access. Since the bacteria reductions from cropland and pasture loads relate primarily to livestock manure, they will also reduce nutrient loads from these sources. The livestock exclusion BMP will further reduce loads of nutrients and sediment.

Therefore, sediment TMDLs will be developed to address the biological impairments in Upper Little Otter River, Johns Creek, Wells Creek, the Lower Little Otter River, and Buffalo Creek. The nutrient impairment in the Lower Little Otter River will be addressed through the effluent permitting process with the suspected WWTP point source.

Chapter 4: SETTING REFERENCE TMDL LOADS

Since there are no in-stream water quality standards for sediment in Virginia, an alternate method was needed for establishing a reference endpoint that would represent the "non-impaired" condition.

In the past, a reference watershed approach has been used based on a single reference watershed that has similar characteristics as the impaired watershed, except that it has a healthy biological community. One problem with this approach can be finding a suitable reference watershed, especially in minimally-impaired and urban watersheds. A second problem with this approach is in identifying the threshold sediment load that is sufficient for attainment of biological integrity, since the load from the reference watershed may be overly conservative.

For the Little Otter River and Buffalo Creek impairments, the procedure used to set TMDL sediment endpoint loads is a modification of the methodology used to address sediment impairments in Maryland's non-tidal watersheds (MDE, 2006, 2009), hereafter referred to as the "all-forest load multiplier", or the AllForX, approach. The AllForX approach was modified and adapted for a localized application based on a regression of the Virginia Stream Condition Index (VSCI) biological index scores from the impaired watersheds and a selection of multiple healthy comparison watersheds and their corresponding all-forest load multipliers (AllForX), a unit-less measure that represents the magnitude of the existing load beyond that of an all-forest condition.

The sediment TMDL load for each impaired watershed was calculated as the value of AllForX at the VSCI impairment threshold (VSCI < 60) times the all-forest sediment load of the impaired watershed. Since a number of watersheds are used to set the regression, a confidence interval around the threshold was quantified and used to calculate the margin of safety in the Total Maximum Daily Load equation. This approach is an improvement over the reference watershed approach as the sediment endpoint is directly linked with the biological index. The relationship between AllForX and the biological condition is further validated with plots and regressions between AllForX and various independent sediment-related habitat metrics.

4.1. Selection of Local Comparison Watersheds

The selected comparison watersheds were nearby watersheds that have healthy biological communities as measured by the VSCI. Additional criteria used for selection of the comparison watersheds included:

- The same river basin as the impaired stream, preferably
- 1st - 3rd order streams, preferably
- More than one DEQ biological sample

Four comparison watersheds were identified for application of the AllForX approach with the Little Otter River and Buffalo Creek watersheds. Although not all selected watersheds were in the same major river basin as shown in Table 4-1, they were all on the same side of the Appalachian Mountains to prevent major orographic differences. Although two of the selected comparison watersheds were of a larger stream order, their watersheds were not that different in size from the combined Little Otter River sub-watersheds which impact the most downstream impaired segment. While initially it was considered preferable that all comparison watersheds be in the same eco-region as well, the location of the impaired watersheds was very close to the eco-region boundaries, so this criterion was relaxed. While not all criteria were met, the proximity of these healthy watersheds to the impaired watersheds was used as the overriding factor in their selection. Table 4-1 summarizes the various characteristics in support of the selection criteria, while Figure 4-1 illustrates the proximity of the comparison watersheds to the impaired watersheds. Further modeling details on this procedure are presented in the following chapter.

Table 4-1. Summary of Impaired and Comparison Watershed Characteristics

DEQ Station ID	Stream Name	River Basin	Stream Order	Level III Eco-region	Modeling Watershed	Watershed Area (acres)	No. of Biological Samples	Average VSCI
Buffalo Creek Stations								
4ABWA002.00	Lower Buffalo Creek	Roanoke River	2	Piedmont (45)	BWA1	8,600	2	58.4
4ABWA008.53	Upper Buffalo Creek	Roanoke River	3	Piedmont (45)	BWA2	7,112	5	42.7
Little Otter River Stations								
4AJHN000.01	Johns Creek	Roanoke River	2	Piedmont (45)	JHN	2,680	9	41.9
4ALOR007.20	Lower Little Otter River	Roanoke River	3	Piedmont (45)	LOR1	8,949	4	54.0
4ALOR008.64							1	56.5
4ALOR012.20			2				2	58.2
4ALOR014.33			2				11	48.0
4ALOR014.75	Upper Little Otter River	Roanoke River	2	Piedmont (45)	LOR2	14,726	13	55.3
4AWEL000.59	Wells Creek	Roanoke River	2	Piedmont (45)	WEL	3,525	2	52.6
4AWEL001.14							3	49.1
Stations at Comparison Watersheds								
2-BLD000.22	Buffalo Creek	James River	4	Ridge and Valley (67)	BLD	79,214	9	66.4
2-BNF003.52	N.F. Buffalo River	James River	2	Blue Ridge Mountains (66)	BNF	3,641	7	78.0
4ACNT001.32	Big Chestnut Creek	Roanoke River	4	Piedmont (45)	CNT	39,233	5	75.2
4AGCR000.01	Green Creek	Roanoke River	1	Piedmont (45)	GCR	5,894	13	68.0

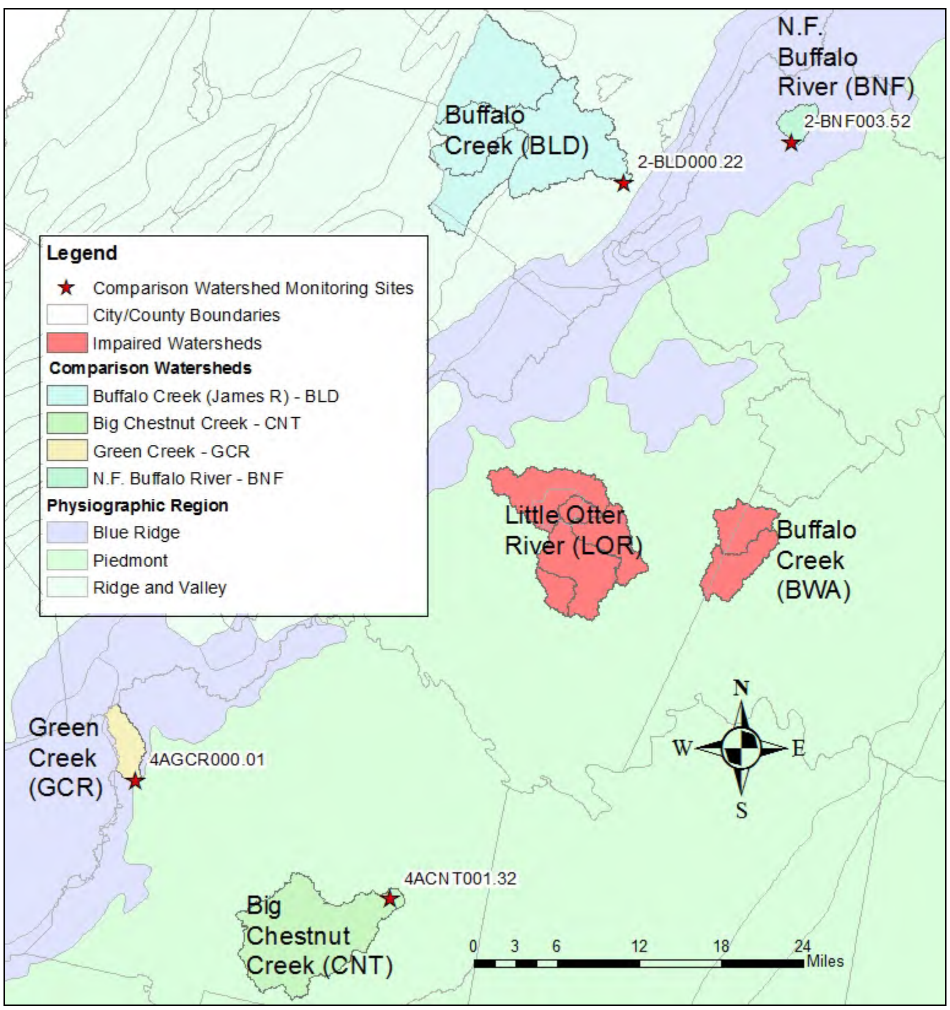


Figure 4-1. Location of Impaired and Comparison Watersheds

Although sediment is used as a surrogate for benthic health in the development of this TMDL, attainment of a healthy benthic community will ultimately be based on biological monitoring of the benthic macro-invertebrate community, in accordance with established DEQ protocols. If a future review should find that the reductions called for in these TMDLs based on current modeling are found to be insufficiently protective of local water quality, then revision(s) will be made as necessary to provide reasonable assurance that water quality goals will be achieved.

Chapter 5: MODELING PROCESS FOR DEVELOPMENT OF THE TMDLS

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutant(s) and that cause the impairment of the water body of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In the development of the sediment TMDLs for the Little Otter River and Buffalo Creek watersheds, the relationship between pollutant sources and pollutant loading to the stream was defined by land uses and areas assessed from the NASS 2009 cropland data layer, together with non-land based loads and simulated output from a computer watershed loading model. The modeling process, input data requirements, and TMDL load calculation procedures are discussed in this chapter.

5.1. Sediment Source Assessment

Sediment is generated in the Little Otter River and Buffalo Creek watersheds through the processes of surface runoff, in-channel disturbances, and streambank and channel erosion, as well as from natural background contributions. Sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, mining, transportation, and residential land uses.

During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to washoff during rainfall events. Sediment generated from impervious areas can be reduced through the use of management practices that reduce the surface load subject to washoff.

Permitted sediment dischargers in Buffalo Creek and Little Otter River include both stormwater and point source facilities. Stormwater discharges include construction permits regulated through Virginia's Erosion and Sediment Control Program and urban stormwater runoff from MS-4, municipal, industrial and general permits. Point source dischargers include individual VPDES facilities, as well as those that fall under the broader aggregate General Permits. All permitted stormwater and point source dischargers have requirements for installation of best management practices (BMPs) to minimize the impact of their activities on water quality.

5.2. Model Selection

The model selected for development of the sediment TMDLs in the Little Otter River and Buffalo Creek watersheds was the Generalized Watershed Loading Functions (GWLF) model, originally developed by Haith et al. (1992), with modifications by Evans et al. (2001), Yagow et al. (2002), and Yagow and Hession (2007). The model was run in metric units and converted to English units for this report.

The loading functions upon which the GWLF model is based are compromises between the empiricism of export coefficients and the complexity of process-based simulation models. GWLF is a continuous simulation spatially-lumped parameter model that operates on a daily time step. The model estimates runoff, sediment, and dissolved and attached nitrogen and phosphorus loads delivered to streams from complex watersheds with a combination of point and non-point sources of pollution. The model considers flow inputs from both surface runoff and groundwater. The hydrology in the model is simulated with a daily water balance procedure that considers different types of storages within the system. Runoff is generated based on the Soil Conservation Service's Curve Number method as presented in Technical Release 55 (SCS, 1986).

GWLF uses three input files for weather, transport, and nutrient data. The weather file contains daily temperature and precipitation for the period of simulation. The transport file contains input data primarily related to hydrology and sediment transport, while the nutrient file contains primarily nutrient values for the various land uses, point sources, and septic system types. The Penn State Visual Basic™ version of GWLF with modifications for use with ArcView was the starting point for additional modifications (Evans et al., 2001). The following modifications related to sediment were made to the Penn State version of the GWLF model, as incorporated in their ArcView interface for the model, AvGWLF v. 3.2:

- Urban sediment buildup was added as a variable input.
- Urban sediment washoff from impervious areas was added to total sediment load.
- Formulas for calculating monthly sediment yield by land use were corrected.
- Mean channel depth was added as a variable to the streambank erosion calculation.

The current Virginia Tech (VT) modified version of GWLF (Yagow and Hession, 2007) was used in this study. The VT version includes a correction to the flow accumulation calculation in the channel erosion routine that was implemented in December 2005 (VADEQ, 2005). This version also includes modifications from Schneiderman et al. (2002) to include an unsaturated zone leakage coefficient, and to add in missing bounds for the calculation of erosivity using Richardson equations which were intended to have minimum and maximum bounds on daily calculations. These minimum and maximum bounds were not included in GWLF 2.0, and have been added to keep calculations within physically expected bounds.

Erosion is generated using a modification of the Universal Soil Loss Equation. Sediment supply uses a delivery ratio together with the erosion estimates, and sediment transport takes into consideration the transport capacity of the runoff. Stream bank and channel erosion was calculated using an algorithm by Evans et al. (2003) as incorporated in the AVGWLF version (Evans et al., 2001) of the GWLF model and corrected for a flow accumulation coding error (VADEQ, 2005).

5.3. GWLF Model Development for Sediment

Since simulated sediment loads were required from the comparison watersheds as well as from the watersheds corresponding to the impaired segments in the Little Otter River and Buffalo Creek, model input data were created for each of the four comparison watersheds, for the four sub-watersheds corresponding with the impaired segments on Little Otter River and its tributaries, and for the two sub-watersheds contributing to the impaired segments on Buffalo Creek. Additionally, a portion of the Big Otter River watershed was used as a surrogate for calibrating hydrologic parameters. Model development for all watersheds was performed by assessing the sources of sediment in the watershed, evaluating the necessary parameters for modeling loads, calibrating to observed flow data, and finally applying the model and procedures for calculating loads.

Since some of the headwater watersheds are nested within downstream watersheds, the land segments were simulated uniquely, so that the land areas and associated loads do not overlap. For example, in the Buffalo Creek watershed, areas and associated loads from the Upper Buffalo Creek and Lower Buffalo Creek watersheds would need to be added together to sum for the entire watershed. Similarly in the Little Otter River watershed, the Upper Little Otter River, Johns Creek, and Wells Creek watersheds are all exclusive headwater segments, but the Lower Little Otter River receives inputs from all three, so that areas and associated loads would need to be summed for all four watersheds for totals for the Little Otter River.

The six impaired segments and their corresponding sub-watersheds are shown in Figure 5-1.

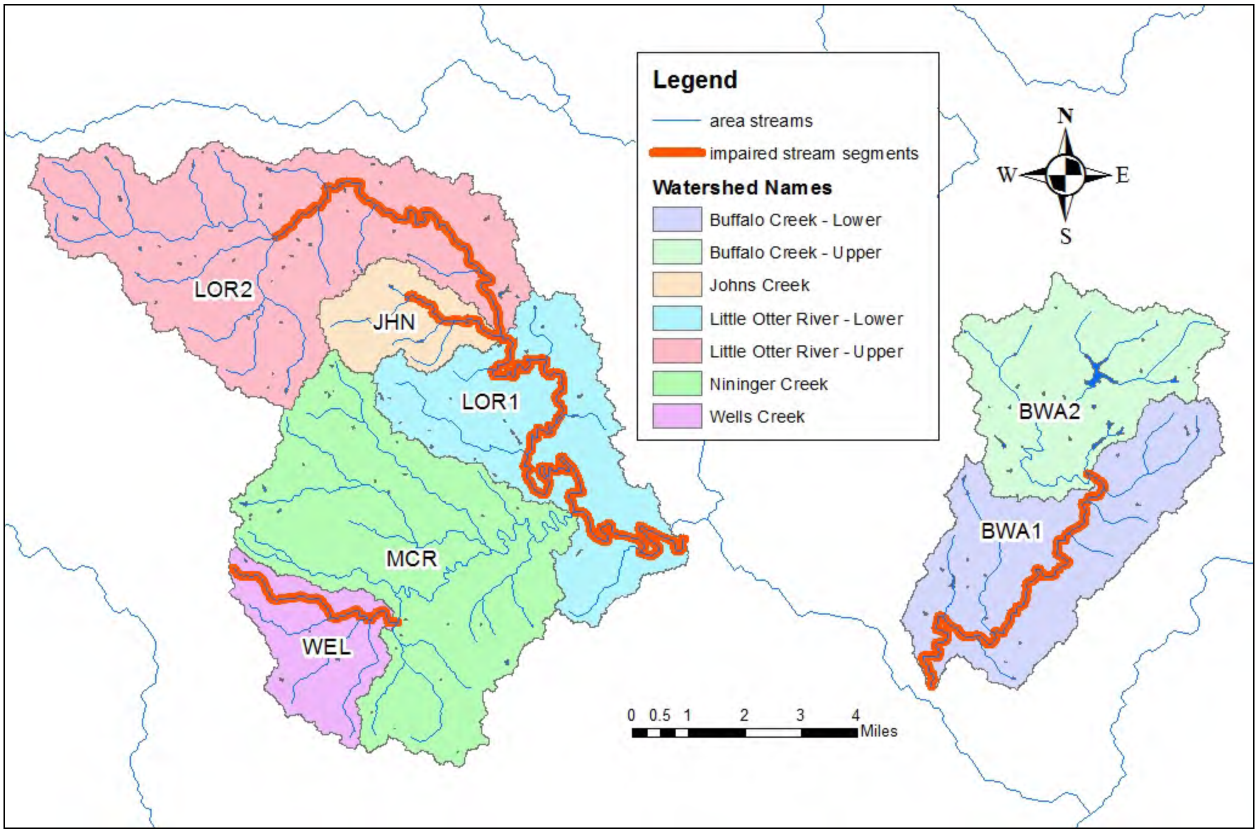


Figure 5-1. GWLF Modeling Sub-watersheds in Little Otter River and Buffalo Creek

5.4. Input Data Requirements

5.4.1. Climate Data

The climates in Little Otter River and Buffalo Creek watersheds were characterized by meteorological observations from the National Weather Service Cooperative Station 440561 at Bedford, Virginia and Station 445120 at Lynchburg Regional Airport, respectively. For the comparison watersheds, the climates at the two James River watersheds (BLD and BNF) used data from Station 446593 at Pedlar Dam, while Green Creek (GCR) used data from Station 441999 at Copper Hill and Big Chestnut Creek (CNT) used data from Station 447338 at Rocky Mount. The period of record used for TMDL modeling was a nineteen-year period from January 1992 through December 2010, with the preceding 9 months of data used to initialize storage parameters. The Big Otter River (BOR) watershed used for hydrologic calibration was simulated with the Bedford 440561 weather and compared with corresponding observed daily discharge from the USGS station 02061000 for the period January 2008 through December 2011. The locations of the various NCDC stations are shown in relationship to the Little Otter River, Buffalo Creek, the comparison watersheds, and the hydrologic calibration watershed in Figure 5-2.

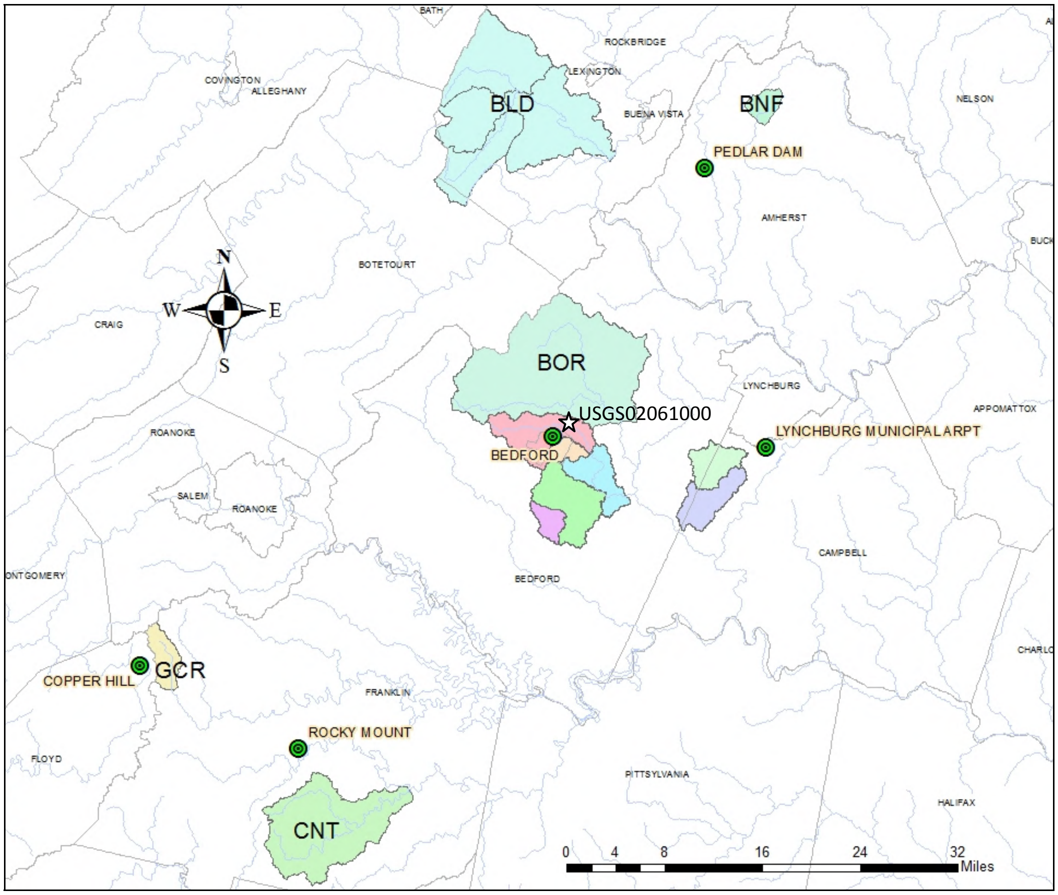


Figure 5-2. Location of Weather and Discharge Stations

5.4.2. Existing Land Use

Modeled land uses for the Little Otter River, the Buffalo Creek, the hydrologic calibration, and the comparison watersheds were derived from the USDA National Agricultural Statistics Service digital cropland data layer for 2009, as discussed in Section 2.5. The NASS categories were consolidated into general land use categories of Row Crop, Hay, Pasture, Forest, and various “developed urban ” categories, as shown in Table 5-1.

Table 5-1. NASS Land Use Group Distributions

		NASS Land Use Groups										
		Row Crop	Hay	Pasture	Forest	Barren	Urban open space	LDI	MDI	HDI	Water	Total
Impaired Watersheds		Area in acres										
Lower Buffalo Creek	BWA1	7.0	1,083.2	1,280.2	5,574.7	25.9	522.7	101.5	3.1	1.5	8.5	8,608.4
Upper Buffalo Creek	BWA2	55.8	1,176.0	844.2	2,416.9	103.5	1,424.6	877.2	179.8	33.3	88.3	7,199.6
Lower Little Otter River	LOR1	141.0	2,880.9	1,247.1	3,724.2	18.0	555.4	310.0	24.8	3.9	6.2	8,911.4
Machine Creek	MCR	232.5	5,086.4	2,196.2	5,574.7	20.7	775.1	246.4	3.1	0.8	8.5	14,144.4
Wells Creek	WEL	7.0	1,688.6	727.6	881.8	4.1	167.1	36.4	0.0	0.0	6.2	3,518.8
Johns Creek	JHN	15.5	320.0	145.7	971.0	24.3	405.8	563.4	171.3	63.5	0.8	2,681.2
Upper Little Otter River	LOR2	31.0	4,597.1	1,984.1	4,868.7	62.5	1,612.8	1,266.2	182.1	39.5	13.9	14,658.1
Non-impaired Comparison Watersheds												
Buffalo Creek	BLD	465.7	16,092.0	314.6	57,722.2	45.7	4,146.7	417.7	8.5	0.8	69.7	79,283.6
N.F. Buffalo River	BNF	0.0	0.8	0.0	3,587.9	0.5	52.2	0.0	0.0	0.0	0.0	3,641.3
Big Chestnut Creek	CNT	711.4	3,959.8	4,165.2	28,499.2	18.7	1,639.6	203.8	30.2	4.6	59.7	39,292.3
Green Creek	GCR	3.1	199.9	38.0	5,449.2	2.0	201.8	0.0	0.0	0.0	1.5	5,895.6
Hydrologic Calibration Watershed												
Big Otter River	BOR	175.1	17,948.4	91.4	50,492.8	38.5	3,292.8	554.8	10.8	0.0	172.8	72,777.6

LDI = low intensity developed; MDI = medium intensity developed; HDI = high intensity developed

The Row Crop category was subdivided into hi-till and low-till categories based on Conservation Tillage Information Center (CTIC) data as incorporated in the 2006 Virginia Statewide NPS Watershed Assessment (Yagow and Hession, 2007). The Hay and Pasture acreages were combined and reassigned based on percent distribution by VAHU6, also as used in the Yagow and Hession study (2007). From the Pasture category, the “riparian”, and “animal feeding operation” land uses were calculated as 0.0497 and 0.00582 times the total Pasture area, respectively, as estimated from proportions within the Chesapeake Bay Watershed Model (CBWM) land-river segment OR2_7610_7780. The remaining Pasture area was sub-divided into 10% “good”, 70% “fair”, and 20% “poor” pasture land uses, based on an assessment by local conservation personnel. A “harvested forest” land use was created as 1% of the Forest category, similar to procedures used in the CBWM (USEPA, 2010). The “barren” category was re-assessed as 1.6% of all the developed land use categories for Buffalo Creek, as half that rate (0.8%) for Little Otter River sub-areas and as 0.4% for the less developed comparison and calibration watersheds, and subtracted from the “Urban Open Space” land use. Half of the “barren” areas were assumed to be subject to VSMP requirements, while the other half were assumed to be disturbed areas in parcels below the minimum size subject to VSMP permits. The “developed” categories were sub-divided into pervious and impervious portions, with “urban open space” assigned to the pervious portion of the “low intensity developed” land use. Impervious percentages of 20%, 50%, and 80% were used, respectively, for the low intensity, medium intensity and high intensity developed areas. The simulated land uses and their derivations are summarized in Table 5-2, while detailed distributions are included in the appendix.

Table 5-2. Modeled Land Use Categories

NASS Groups	NASS Land Uses	% Impervious	Modeled Land Use Categories
Row Crop	Corn, sorghum, soybeans, winter wheat, etc.	0	Hi-till cropland
			Lo-till cropland
Hay	Alfalfa, other hays	0	Hay
Pasture	Pasture/grass, shrubland, grassland herbaceous	0	Good pasture
			Fair pasture
			Poor Pasture
			Riparian pasture
			Animal feeding operation
Forest	Deciduous forest, evergreen forest, mixed forest,	0	Forest
			Harvested forest
Barren	Barren	0	Barren
Open Space	Urban open space	0	Pervious LDI
LDI	Developed, low intensity	20	Impervious LDI
			Pervious LDI
MDI	Developed, medium intensity	50	Impervious MDI
			Pervious MDI
HDI	Developed, high intensity	80	Impervious HDI
			Pervious HDI

Each land use within a sub-watershed formed a hydrologic response unit (HRU). Model parameters were then calculated for each HRU using GIS analysis to reflect the variability in topographic and soil characteristics across the watershed. A description of model parameters follows in section 5.5.

5.5. Future Land Use

A future land use scenario was created using the same land use categories as for the existing scenario. Future land use was assessed from a combination of the Bedford County Future Land Use spatial data layer associated with the Bedford County 2025 Comprehensive Plan, the City of Bedford 2012 Comprehensive Plan (no map), the Campbell County on-line GIS data layers for tax parcels and zoning, and the U.S. Census Bureau data for the area in both 2000 and 2010. For those areas where spatial data were available, an assessment was made of current agricultural land (agland) and forest land zoned for development. Population change between 2000 and 2010 was then evaluated. Based on a combination of the 10-yr percent change in population, the potential for future agland reduction and forest land reduction, and a visual assessment of the availability of land already sub-divided into smaller parcels (Campbell County only), a percent reduction in agland and forest land was assigned to each sub-watershed, as shown in Table 5-3.

Table 5-3. Future Land Use Change Assessment Summary

Sub-watershed	Population			Total Area (acres)	Agland zoned for Development			Forest zoned for Development			Assigned Future Ag Reduction	Assigned Future Forest Reduction	Rationale
	2000	2010	10-yr percent change		Bedford County (acres)	Bedford City (acres)	Potential Future Ag Reduction	Bedford County (acres)	Bedford City (acres)	Potential Future Forest Reduction			
Buffalo Creek - Lower	2,435	2,741	12.60%	1,538.4	69.4	0.0	4.5%	147.7	0.0	9.6%	5.0%	20.0%	estimated as 2x the forest change% in Upper BWA + availability of small parcels*
Buffalo Creek - Upper	8,884	9,811	10.40%	2,941.0	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0%	10.0%	used pop change% + availability of small parcels*
Johns Creek	2,456	2,414	-1.70%	2,680.6	125.9	174.7	11.2%	275.3	251.0	19.6%	11.0%	20.0%	estimated as % zoning change
Little Otter River - Lower	1,089	1,339	22.90%	8,906.8	92.4	9.9	1.1%	134.3	8.0	1.6%	1.0%	2.0%	estimated as % zoning change
Little Otter River - Upper	5,214	6,150	17.90%	14,696.4	1,790.3	565.3	16.0%	1,502.5	572.3	14.1%	16.0%	14.0%	estimated as % zoning change
Machine Creek	1,514	1,594	5.20%	14,166.3	420.0	12.9	3.1%	276.5	14.5	2.1%	3.0%	2.0%	estimated as % zoning change
Wells Creek	355	436	22.80%	3,560.7	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0%	0.0%	all zoned agriculture - unlikely future change

Campbell County was assessed visually through their on-line GIS.
* - Many parcels already sub-divided into small parcels in the Buffalo Creek watershed, suitable for development.

The future land use scenario was then constructed by reducing all agriculture and forestry land uses by their respective reduction percentages and redistributing the changed acreage on proportional basis to all developed land use categories. An additional change was added to account for a recent new development along Waterlick Road in the Upper Buffalo Creek watershed, with 4.96 acres of Urban Open Space changed to high intensity developed. Detailed tables of the land use distribution for the future land use scenario are included in the appendix.

5.6. GWLF Parameter Evaluation

All parameters were evaluated in a consistent manner for all watersheds in order to ensure their comparability. All GWLF parameter values were evaluated from a combination of GWLF user manual guidance (Haith et al., 1992), AVGWLF procedures (Evans et al., 2001), procedures developed during the 2006 statewide NPS pollution assessment (Yagow and Hession, 2007), and best professional judgment.

Hydrologic and sediment parameters are all included in GWLF's transport input file, with the exception of urban sediment buildup rates, which are in the nutrient input file. Descriptions of each of the hydrologic and sediment parameters are listed below according to whether the parameters were related to the overall watershed, to the month of the year, or to individual land uses.

5.6.1. Hydrology Parameters

Watershed-Related Parameter Descriptions

- Unsaturated Soil Moisture Capacity (SMC, cm): The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute - available water capacity.
- Recession coefficient (day^{-1}): The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph. This parameter was evaluated using the following relationship from Lee et al. (2000): RecCoeff = 0.045+1.13/(0.306+Area in square kilometers)
- Seepage coefficient: The seepage coefficient represents the fraction of flow lost as seepage to deep storage.
- Leakage coefficient: The leakage coefficient represents the fraction of infiltration that bypasses the unsaturated zone through macro-pore flow. An increase in this coefficient, initially set to zero, decreases ET losses and increases baseflow.

The following parameters were initialized by running the model for a 9-month period prior to the period used for load calculation:

- Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.
- Initial saturated storage (cm): Initial depth of water stored in the saturated zone.
- Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.
- Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the current day.

Month-Related Parameter Descriptions

- Month: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model.
- ET_CV: Composite evapotranspiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.
- Hours per Day: Mean number of daylight hours.
- Erosion Coefficient: This is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Each region is assigned separate coefficients for the months October-March, and for April-September.

Land Use-Related Parameter Descriptions

- Curve Number: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event, evaluated using SCS TR-55 guidance.

5.6.2. Sediment Parameters

Watershed-Related Parameter Descriptions

- Sediment delivery ratio: The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as an inverse function of watershed size (Evans et al., 2001).

Land Use-Related Parameter Descriptions

- USLE K-factor: The soil erodibility factor was calculated as an area-weighted average of all component soil types.
- USLE LS-factor: This factor is calculated from slope and slope length measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.
- USLE C-factor: The vegetative cover factor for each land use was evaluated following GWLF manual guidance, Wischmeier and Smith (1978), and Hession et al. (1997); and then adjusted after consultation with local NRCS personnel.
- Daily sediment buildup rate on impervious surfaces: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.

Streambank Erosion Parameter Descriptions (Evans et al., 2003)

- % Developed land: percentage of the watershed with urban-related land uses – defined as all land in MDR and HDR land uses, as well as the impervious portions of LDR.
- Animal density: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by the watershed area in acres. The number of AU was estimated as 1 AU per 6 acres of available pasture.
- Curve Number: area-weighted average value for the watershed.
- K Factor: area-weighted USLE soil erodibility factor for the watershed.
- Slope: mean percent slope for the watershed.
- Stream length: calculated as the total stream length of natural perennial stream channels, in meters. Excludes any non-erosive hardened and piped sections of the stream.
- Mean channel depth (m): calculated from relationships developed either by the Chesapeake Bay Program or by USDA-NRCS by physiographic region, of the general form – $y = a * A^b$, where y = mean channel depth in ft, and A = drainage area in square miles (USDA-NRCS, 2005).

5.7. Supplemental Post-Model Processing

After modeling was performed on individual and cumulative sub-watersheds, model output was post-processed in a Microsoft Excel™ spreadsheet to summarize the modeling results and to account for existing levels of BMPs already implemented within each watershed.

The extent and effect of existing agricultural BMPs in the impaired watersheds were based on data extracted from Virginia DCR's online agricultural BMP database for each of the three sixth-order watersheds encompassing these watersheds, namely RU53 (Wells Creek and Machine Creek), RU54 (Upper and Lower Little Otter Creek and Johns Creek), and RU56 (Upper and Lower Buffalo Creek).

The extent and effect of existing agricultural BMPs on the reference and calibration watersheds were based on the pass-through fractions of the sediment load from each land use in each HUP as developed by Virginia DCR previously for the Virginia 2006 Statewide NPS Pollution Assessment (Yagow and Hession, 2007). Modeled sediment loads within each land use category were then multiplied by their respective pass-through fractions to simulate the reduced loads resulting from existing BMPs.

Since the dam on Timberlake was rebuilt recently (1995), it effectively serves as a sediment trap for upland areas in that watershed. The area draining into the lake was calculated as 1,221.26 ha of the total area of 2,939.55 ha in the Upper Buffalo Creek watershed. A sediment trapping efficiency of 50% was then additionally applied to this fraction of the watershed and associated sediment loads.

Sediment BMPs are required on harvested forest lands and on disturbed lands subject to Erosion and Sediment (E&S) regulations. A sediment efficiency of 25.5% was used for BMPs on harvested forest land (USEPA, 2010), while sediment reductions on half of the existing disturbed land was assumed to be subject to E&S permits at a sediment efficiency of 40%.

5.8. Representation of Sediment Sources

5.8.1. Surface Runoff

Pervious area sediment loads were modeled using a modified USLE erosion detachment algorithm, monthly transport capacity calculations, and a sediment delivery ratio in the GWLF model to calculate loads at the watershed outlet. Impervious area sediment loads were modeled in the GWLF model using an exponential buildup-washoff algorithm.

5.8.2. Channel and Streambank Erosion

Streambank erosion was modeled within the GWLF model using a modification of the routine included in the AVGWLF version of the GWLF model (Evans et al., 2001). This routine calculates average annual streambank erosion as a function of percent developed land, average area-weighted curve number (CN) and K-factors, watershed animal density, average slope, streamflow volume, mean channel depth, and total stream length in the watershed. Livestock population, which figures into animal density, was estimated based on a stocking density of 0.167 animal units per acre of available pasture (AU/acre).

5.8.3. Industrial Stormwater

Currently, there are six (6) active Industrial Storm Water General Permits (ISWGPs) in the Little Otter River watersheds, and one (1) in the Buffalo Creek watersheds. Current loads for each facility were simulated as part of the urban pervious and impervious land use categories. Permitted WLA loads for each facility were calculated as the permitted area of the facility times the permitted average TSS concentration of 100 mg/L times the average annual runoff (simulated for low intensity developed areas), as shown in Table 5-4.

Table 5-4. Industrial Stormwater General Permit (ISWGP) WLA Loads

Facility Name	VPDES Permit Number	Source Type	Receiving Stream	Area (acres)	Permitted Average TSS Concentration (mg/L)	Average Annual Runoff (in/yr)	TSS WLA (tons/yr)
Sam Moore Furniture LLC	VAR050528	ISWGP	Johns Creek	20	100	19.05	4.32
Hilltop Lumber Co Inc	VAR050544	ISWGP	Upper Little Otter River	11.87	100	19.05	2.56
Rubatex International LLC	VAR050733	ISWGP	Johns Creek	7.27	100	19.05	1.57
Bedford County - Sanitary Landfill	VAR051233	ISWGP	Machine Creek UT	52	100	19.05	11.22
Bedford City - Hylton Site	VAR051369	ISWGP	Johns Creek	20	100	19.05	4.32
Central VA Pallet and Stake Co	VAR052107	ISWGP	Upper Little Otter River	11.73	100	19.05	2.53
New London Auto Parts Inc	VAR051801	ISWGP	Lower Buffalo Creek	19.05	100	16.86	3.64

Load = X acres * Y mg/L * Z in/yr * 102,801.6 L/acre-inch * 1 lb/453,600 mg * 1 ton/2000 lbs = X * Y * Z * 0.000113317 tons/yr

5.8.1. Construction Stormwater

Between January 2008 and June 2012, there have been 10 land disturbing (construction stormwater) permits issued in the Bedford County portion of the Buffalo Creek watersheds representing a total disturbed acreage of 17.04 acres. Of those permits, 4 are current, comprising a total of 8.34 acres. In the Campbell County portion of the Buffalo Creek watersheds, local construction permits were reported since 2010, totaling 35.13 acres of disturbed land, of which 23.3 acres were for single family construction and the rest for commercial construction.

In the Little Otter River watersheds, there have been 29 land disturbing (construction stormwater) permits issued between January 2008 and June 2012, representing a total disturbed acreage of 35.60 acres. Of those permits, 6 are current, comprising a total of 3.25 acres. Additional local construction permits for areas < 5 acres in size may also exist for single family construction and other small-scale construction.

Based on the more complete reported data in the Buffalo Creek watershed, barren land was calculated as a percentage of developed land in that watershed (0.79%), rounded to 0.80%, and applied to both the Upper and Lower Buffalo Creek watersheds. Since development rates were lower in the Little Otter River, with current reported rates suspected to be low, they were estimated as half of the rate (0.40% of developed land) in the Buffalo Creek watersheds and applied to the developed land in each Little Otter River sub-area. Aggregated construction WLA loads for each sub-watershed were calculated as the permitted area times the permitted average TSS concentration of 60 mg/L times the simulated average annual runoff for the “barren” land use, as shown in Table 5-5.

Table 5-5. Aggregated Construction WLA Loads

Receiving Stream	Area (acres)	Permitted Average TSS Concentration (mg/L)	Average Annual Runoff (in/yr)	Aggregated TSS Load (tons/yr)
Lower Buffalo Creek	5.24	60	14.94	0.53
Upper Buffalo Creek	20.95	60	14.94	2.13
Lower Little Otter River	3.65	60	15.76	0.39
Machine Creek	4.18	60	15.76	0.45
Wells Creek	0.83	60	15.76	0.09
Johns Creek	4.91	60	15.76	0.53
Upper Little Otter River	12.65	60	15.76	1.36

5.8.1. Municipal Stormwater

There is one MS-4 permit in the Upper Buffalo Creek watershed assigned to the Virginia Department of Transportation which includes its right-of-way (and properties) in the census-defined urbanized areas. The MS-4 area, for the purposes of this report, was defined as the length of major roads within the 2010 census urbanized area in the watershed times a 20-meter (66-foot) buffer to include right-of-way. For Existing conditions, the associated sediment load is simulated as part of the medium intensity developed land use. For future conditions, the MS-4 WLA was calculated as the estimated area times a benchmark TSS concentration times the simulated average annual runoff for the medium intensity developed land use, as shown in Table 5-6.

Table 5-6. MS-4 WLA Load

VPDES Permit Number	Receiving Stream	Area (acres)	Benchmark TSS Concentration (mg/L)	Average Annual Runoff (in/yr)	TSS WLA (tons/yr)
Virginia DOT VA040115	Upper Buffalo Creek	40.19	60	25.45	6.95

5.8.2. Other Permitted Sources (VPDES and General Permits)

There are no general discharge permits for single-family homes in any of these watersheds, and no VPDES permits in the Buffalo Creek watersheds.

In the Little Otter River watersheds, there are two VPDES permits, one general permit, and one integrated discharge permit for a concrete facility. The Existing sediment loads from these sources was calculated as the average daily flow and average daily total suspended solids (TSS) concentration, as reported by the permit holders to DEQ in monthly discharge reports, as shown in Table 5-7. No discharge was reported for the concrete facility.

Table 5-7. Existing Sediment Load from Other Permitted Sources

Facility Name	Permit Number	Permit Type	Receiving Stream	Existing Conditions		
				Average Flow (MGD)	Average [TSS] (mg/L)	TSS Load (tons/yr)
Body Camp Elementary School	VA0020818	VPDES	Wells Creek	0.002	5.0	0.02
Bedford City - WWTP	VA0022390	VPDES	Upper Little Otter River	1.0	7.6	11.57
Bedford City - WTP	VAG640066	General	Upper Little Otter River UT	0.033	0.0	0.00
Bedford Ready Mix Concrete	VAG110014	Concrete	Johns Creek	0.0072	--	--

Load = X mgd * Y mg/L * 10^6 gal/MG * 3.785411 L/gal * 1.1022927 e^{-9} lbs/mg * 365 days/yr = X * Y * 1.523 = Z tons/yr

For the TMDL calculations, the waste load allocation (WLA) was calculated from the permitted average TSS concentration and the design flow for each facility. Where the design flow was not specified, the average daily flow was used for the load calculation. The WLA loads for each facility are shown in Table 5-8.

Table 5-8. WLA Sediment Loads from Other Permitted Sources

Facility Name	Permit Number	Permit Type	Receiving Stream	Permitted Conditions		
				Design Flow (MGD)	Permitted Average [TSS] (mg/L)	TSS WLA* (tons/yr)
Body Camp Elementary School	VA0020818	VPDES	Wells Creek	--	30	0.10
Bedford City - WWTP	VA0022390	VPDES	Upper Little Otter River	2.0	30	91.38
Bedford City - WTP	VAG640066	General	Upper Little Otter River UT	--	30	1.51
Bedford Ready Mix Concrete	VAG110014	Concrete	Johns Creek	0.0072	30	0.33

* Where permitted flow limits are not specified, average daily flow is used for load calculation.

Load = X mgd * Y mg/L * 10^6 gal/MG * 3.785411 L/gal * 1.1022927 e^{-9} lbs/mg * 365 days/yr = X * Y * 1.523 = Z tons/yr

5.9. Accounting for Critical Conditions and Seasonal Variations

5.9.1. Selection of Representative Modeling Period

Selection of the modeling period was based on the availability of daily weather data and the need to represent variability in weather patterns over time in the watershed. A long period of weather inputs was selected to represent long-term variability in the watershed. The model was run using a weather time series from April 1991 through December 2010, with the first 9 months used as an initialization period for internal storages within the model. The remaining 19-year period was used to calculate average annual sediment loads in all watersheds.

5.9.2. Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was chosen as a multi-year period that was representative of typical weather conditions for the area, and included "dry", "normal" and "wet" years. The model, therefore, incorporated the variable inputs needed to represent critical conditions during low flow – generally associated with point source loads – and critical conditions during high flow – generally associated with nonpoint source loads.

5.9.3. Seasonal Variability

The GWLF model used for this analysis considered seasonal variation through a number of mechanisms. Daily time steps were used for weather data and water balance calculations. The model also used monthly-variable parameter inputs for evapo-transpiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients for user-specified growing season months.

5.10. Model Calibration of Hydrology

Model calibration is the process of adjusting model parameter values so that simulated loads from a watershed match loads calculated from corresponding monitored ("observed") flow and concentrations at a given point in a stream. Although GWLF was originally developed for use in non-gaged watersheds and, therefore, does not require calibration, hydrologic calibration has been recommended where observed flow data is available (Dai et al., 2000). In-stream observed discharge data were not available in any of the Little Otter River or Buffalo Creek sub-watersheds, but were available in a similar-sized neighboring watershed, the Big Otter River. Hydrologic calibration was performed using this surrogate watershed, and the calibration adjustments applied to all of the Little Otter River, Buffalo Creek and comparison watersheds for the TMDL modeling.

The purpose of calibration was to adjust parameter values within the model so that simulated model output more closely matched observed data. By calibrating to total flow and seasonal flow distribution, simulation of the hydrology-dependent sediment load components should also be more representative of watershed conditions.

Daily discharge records were available at the USGS station 0206100 on the Big Otter River, adjacent to the Little Otter River, from December 2006 through the present. A model of the Big Otter River was constructed as discussed previously and discharge simulated for the 4-yr calibration period, January 2008 through December 2011. Observed monthly discharge was then compared with GWLF simulated flow for the surrogate watershed.

GWLF uses daily rainfall inputs and generates monthly runoff outputs. Hydrologic calibration was performed based on monthly runoff (flow) totals. The parameters adjusted during hydrologic calibration included the recession coefficient, the seepage coefficient, the leakage coefficient, the soil available water content (AWC), and area-weighted dormant- and growing-season ET cover coefficients.

Spreadsheets were constructed and used to analyze model output after each model run, and to calculate parameter adjustments for the next iteration of calibration. Within the spreadsheets, comparisons were made between simulated and observed runoff for the flow components, seasonal distribution, monthly runoff time series, and cumulative runoff. Total flow was calibrated through adjustments to the seepage and leakage coefficients, while seasonal distribution was calibrated by adjusting the area-weighted dormant-season ET cover coefficients.

The results of the hydrologic calibration for Big Otter River are presented as a monthly runoff time series in Figure 5-3, cumulative runoff in Figure 5-4, and flow and seasonal distributions in Table 5-9.

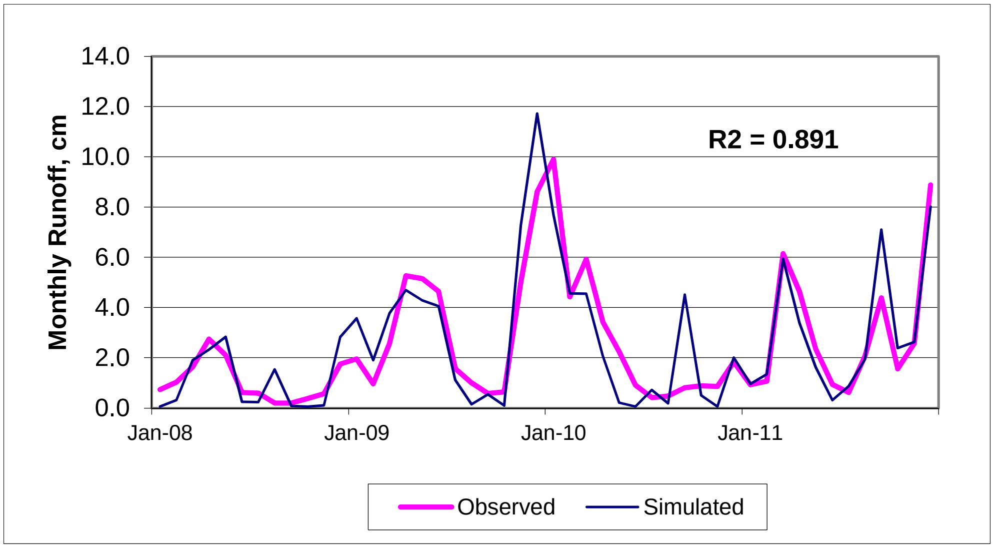


Figure 5-3. Calibration Monthly Runoff Time Series - Big Otter River

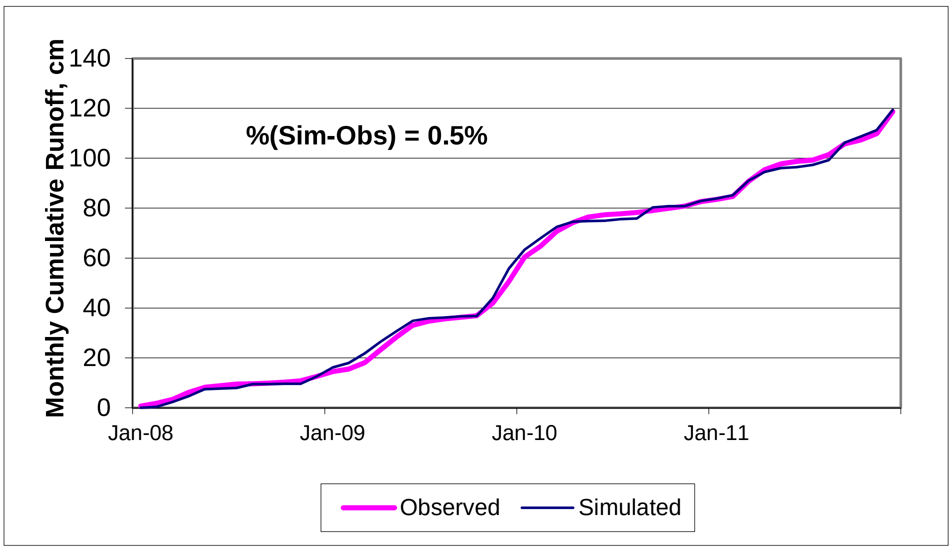


Figure 5-4. Calibration Cumulative Runoff - Big Otter River

Table 5-9. Calibration Flow Distributions - Big Otter River - 2008-2011

Flow Distribution Components	SIMULATED		OBSERVED		Sim-Obs	
	(cm/yr)	(% of Total)	(cm/yr)	(% of Total)	(cm/yr)	(% of Total)
Total Runoff	29.83		29.69		0.14	0.5%
Total Surface Runoff	7.26	24.3%				
Total Baseflow	22.57	75.7%		67.0%		11.5%
Winter (Dec-Feb) Runoff	11.25	37.7%	10.52	35.4%	0.73	7.0%
Spring (Mar-May) Runoff	9.40	31.5%	11.05	37.2%	-1.66	-15.0%
Summer (Jun-Aug) Runoff	2.86	9.6%	3.51	11.8%	-0.66	-18.7%
Fall (Sep-Nov) Runoff	6.33	21.2%	4.60	15.5%	1.73	37.5%

The monthly runoff time series for Big Otter River showed a generally good correspondence between observed and simulated monthly runoff, with a correlation coefficient of 0.89. The simulated seasonal percentages of runoff varied up to 38% of the observed values (mainly due to a mismatch of observed and simulated data in September 2010), although total simulated runoff was only 0.5% less than the observed value. The difference between observed and simulated individual season average annual discharge totals were within ±1.73 cm/season, and the baseflow percentage was within 11.5% of observed baseflow, calculated using the baseflow separation routine of Arnold et al. (1995). Since the TMDL is based on long-term average annual loads and uses comparably parameterized watersheds, the calibrated GWLF model should provide reasonable load comparisons for TMDL development.

In order to further ascertain the appropriateness of the calibrated model for Little Otter River and Buffalo Creek, a variety of average annual metrics were calculated from simulated outputs for the wider range of precipitation inputs to the model as used for TMDL modeling and shown in Table 5-10. These are compared with observed or modeled outputs from other watersheds or monitoring gages in the region. Precipitation input for the watersheds modeled in the current TMDLs are slightly higher than those used in three previous TMDLs in the Shenandoah Valley. Simulated evapotranspiration is therefore slightly higher, as would be expected from larger precipitation inputs. Surface runoff - amount and % of total precipitation – fall within the range of the previous TMDLs. Surface runoff was larger for Abrams Creek, as would be expected from a highly urbanized area. The area-normalized flows are comparable between the current TMDL watersheds and the calibration watershed, as baseflow % was one of the measures used to guide calibration, and within the larger range seen in previous TMDLs. All in all, the calibrated Little Otter River and Buffalo Creek hydrology appear to be reasonable for this region.

Table 5-10. Simulated Metrics Compared with Regional Watersheds

	Current TMDLs		USGS Flow	Previous TMDLs		
Annual Average Values	**Buffalo Creek**	**Little Otter River**	**Big Otter River**	**Abrams Creek**	**Toms Brook**	**Mossy Creek**
Watershed Area (sq.mi.)	25.6	67.7	127.4	19.1	16.4	14.7
Averaging Period	1992-2010	1992-2010	2007-2011	1982-1987	1985-1994	1985-1999
Precipitation (cm/yr)	106.1	113.9		93.2	93.56	96.91
Evapotranspiration (cm/yr)	67.3	68.3		48.0	62.7	45.1
Surface runoff (cm/yr)	8.0	9.4		17.0	5.8	5.7
Surface runoff (% of precipitation)	7.5%	8.3%		18.2%	6.2%	5.8%
Area-normalized Flow (cfsm)	0.78	0.87	0.83	0.97	0.90	1.32
Baseflow (% of Total Streamflow)	70.5%	68.4%	67.0%	61.9%	81.4%	89.1%

5.11. Existing Sediment Loads

Existing sediment loads were simulated for all individual land uses with the calibrated GWLF model and calculated for point sources, as discussed previously. The resulting loads in all impaired and comparison watersheds are given in Table 5-11.

Table 5-11. Existing Sediment Loads in Impaired and Comparison Watersheds

	Impaired Watersheds							Comparison Watersheds			
Land Use/Source Categories	**BWA1**	**BWA2**	**LOR1**	**MCR**	**WEL**	**JHN**	**LOR2**	**BLD**	**BNF**	**CNT**	**GCR**
	Lower Buffalo Creek	**Upper Buffalo Creek**	**Lower Little Otter River**	**Machine Creek**	**Wells Creek**	**Johns Creek**	**Upper Little Otter River**	**Buffalo Creek (BLD)**	**NF Buffalo River**	**Big Chestnut Creek**	**Green Creek**
	Sediment Load (tons/yr)										
HiTill Rowcrop (hit)	12.2	44.7	96.7	76.1	1.8	4.7	8.0	26.8	0.0	510.3	1.3
LoTill Rowcrop (lot)	2.1	7.7	92.2	72.9	1.7	4.5	7.7	170.7	0.0	263.9	0.7
Pasture (pas_g)	24.7	9.4	65.8	28.9	32.5	3.1	53.4	198.7	0.0	52.4	2.8
Pasture (pas_f)	869.2	332.0	2,368.4	1,078.4	1,060.2	109.8	1,887.9	6,488.7	1.4	1,723.4	92.4
Pasture (pas_p)	492.6	192.1	1,363.3	622.1	608.8	63.9	1,087.7	3,714.1	0.8	981.2	53.9
Riparian pasture (trp)	1,124.3	436.8	3,320.7	1,551.4	1,385.5	144.0	2,576.1	8,135.3	1.4	2,225.2	121.5
AFO (afo)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay (hay)	298.0	145.1	1,259.1	782.2	308.5	52.0	689.1	2,041.5	0.5	849.4	50.2
Forest (for)	145.8	26.8	184.4	98.6	18.9	16.4	97.6	2,136.3	388.1	696.0	456.5
Harvested forest (hvf)	13.4	2.5	16.2	8.9	1.7	1.5	8.9	176.1	32.7	60.5	40.0
Transitional (barren)	259.7	169.2	152.6	53.4	11.9	59.6	165.6	235.4	8.4	63.8	26.6
Pervious LDI (pur_LDI)	76.8	163.6	198.8	102.9	23.8	95.1	299.3	844.9	36.2	211.8	135.0
Pervious MDI (pur_MDI)	0.2	4.6	1.6	0.3	0.0	7.9	8.6	0.9	0.0	2.0	0.0
Pervious HDI (pur_HDI)	0.0	0.4	0.0	0.0	0.0	1.1	0.9	0.0	0.0	0.2	0.0
Impervious LDI (imp_LDI)	9.0	16.8	40.3	6.6	0.7	9.7	30.3	14.4	0.0	7.2	0.0
Impervious MDI (imp_MDI)	10.4	26.5	47.3	0.7	0.0	26.7	38.8	2.5	0.0	9.3	0.0
Impervious HDI (imp_HDI)	2.2	4.9	13.6	0.2	0.0	10.0	8.5	0.2	0.0	1.4	0.0
Channel Erosion	30.2	14.3	306.4	38.4	2.7	6.4	55.4	615.2	3.2	324.1	2.3
Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	0.0	0.0	0.0
Total Sediment Load	**3,370.8**	**1,597.4**	**9,527.3**	**4,522.1**	**3,458.8**	**616.3**	**7,035.3**	**24,801.8**	**472.6**	**7,982.0**	**983.3**

5.12. Future Sediment Loads

Future sediment loads were simulated for all land use categories with the calibrated GWLF model with permitted sources calculated at their WLA permit limits, as discussed previously. Since future sediment loads are considered to be the starting loads from which reductions will be required to meet the TMDLs, modeling of the future land uses was only performed on the impaired watersheds. The resulting future loads of sediment, shown in Table 5-12 are simulated as decreasing slightly from existing conditions based on the assessed future land use changes from agriculture to developed land uses.

Table 5-12. Future Sediment Loads in Impaired Watersheds

Land Use/Source Categories	Impaired Watersheds						
	BWA1f	BWA2f	LOR1f	MCR	MCRf	JHNf	LOR2f
	Lower Buffalo Creek	Upper Buffalo Creek	Lower Little Otter River	Machine Creek	Wells Creek	Johns Creek	Upper Little Otter River
	Sediment Load (tons/y		Sediment Load (tons/yr)				
HiTill Rowcrop (hit)	11.8	44.7	99.2	73.8	1.8	4.2	6.7
LoTill Rowcrop (lot)	2.1	7.7	94.6	70.8	1.7	4.0	6.5
Pasture (pas_g)	23.7	9.4	65.0	27.5	32.5	2.8	44.9
Pasture (pas_f)	833.5	332.0	2,342.6	1,030.2	1,060.2	97.7	1,585.4
Pasture (pas_p)	472.3	192.1	1,348.6	594.3	608.8	56.9	913.4
Riparian pasture (trp)	1,077.8	436.9	3,263.6	1,485.2	1,385.5	128.1	2,163.3
AFO (afo)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay (hay)	284.8	145.1	1,223.6	757.6	308.5	46.3	578.7
Forest (for)	118.4	24.1	180.4	96.6	18.9	13.1	83.9
Harvested forest (hvf)	10.9	2.2	15.9	8.7	1.7	1.2	7.7
Transitional (barren)	469.6	182.7	195.8	70.6	11.9	71.1	255.3
Pervious LDI (pur_LDI)	194.3	178.3	248.4	127.9	23.8	106.0	459.7
Pervious MDI (pur_MDI)	3.8	1.5	1.8	0.4	0.0	9.5	13.4
Pervious HDI (pur_HDI)	0.1	0.5	0.0	0.1	0.0	1.3	1.3
Impervious LDI (imp_LDI)	14.9	18.2	53.6	6.4	0.7	9.7	45.9
Impervious MDI (imp_MDI)	16.2	25.5	61.6	0.9	0.0	32.0	60.2
Impervious HDI (imp_HDI)	3.6	6.6	17.5	0.2	0.0	12.0	13.2
Channel Erosion	130.5	15.4	302.2	34.6	2.7	9.2	56.9
Permitted WLA	4.2	9.1	12.1	11.7	0.2	11.1	99.3
Total Sediment Load	**3,672.4**	**1,632.0**	**9,526.5**	**4,397.5**	**3,458.8**	**615.9**	**6,395.5**

5.13. GWLF Model Parameters

The GWLF parameter values used for the Little Otter River and Buffalo Creek watershed simulations are shown in Table 5-13 through Table 5-15. Table 5-13 lists the various watershed-wide parameters and their values, Table 5-14 displays the monthly variable evapo-transpiration cover coefficients, and Table 5-15 shows the land use-related parameters – runoff curve numbers (CN) and the Universal Soil Loss Equation's KLSCP product - used for erosion modeling. Calibrated parameters and their calibrated values are indicated in each of the tables. Corresponding GWLF parameter values for the comparison and calibration watersheds are shown in Table 5-16 through Table 5-18. Since the modeling was performed in metric units, note that all of the input parameters are in metric units, even though the simulated results shown in this report are presented in English units.

Table 5-13. GWLF Watershed Parameters for Little Otter River and Buffalo Creek

GWLF Watershed Parameters	units	Buffalo Creek TMDL		Little Otter River TMDL			
		BWA1	BWA2	LOR1	WEL	JHN	LOR2
recession coefficient	(day^{-1})	0.0772	0.0839	0.0761	0.1228	0.1463	0.0640
seepage coefficient		0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
leakage coefficient		0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
sediment delivery ratio		0.1553	0.1619	0.1540	0.1791	0.1834	0.1339
unsaturated water capacity	(cm)	15.20	14.20	13.16	13.35	13.14	15.03
erosivity coefficient (Nov - Apr)		0.146	0.146	0.102	0.102	0.102	0.102
erosivity coefficient (growing season)		0.270	0.270	0.186	0.186	0.186	0.186
% developed land	(%)	0.3	5.5	1.0	0.2	13.0	3.2
no. of livestock	(AU)	265	227	459	270	52	734
area-weighted runoff curve number		74.16	75.66	72.41	75.36	73.64	73.01
area-weighted soil erodibility		0.281	0.279	0.233	0.244	0.222	0.220
area-weighted slope	(%)	11.46	6.31	12.22	14.81	10.35	12.58
aFactor		0.0000537	0.0001254	0.0000458	0.0000480	0.0002117	0.0000738
total stream length	(m)	19,966.0	18,522.0	35,112.0	12,512.0	7,444.0	48,616.0
Mean Channel Depth	(m)	1.039	0.982	1.050	0.794	0.732	1.220

Table 5-14. GWLF Monthly ET Cover Coefficients – Little Otter River and Buffalo Creek

Watershed	ID	Apr	May	Jun	Jul*	Aug	Sep	Oct	Nov	Dec	Jan**	Feb	Mar
Lower Buffalo Creek	BWA1	0.991	0.991	0.991	**0.991**	0.991	0.990	0.990	0.989	0.988	**0.988**	0.990	0.991
Upper Buffalo Creek	BWA2	0.953	0.950	0.949	**0.949**	0.958	0.966	0.975	0.992	1.000	**1.006**	0.978	0.958
Lower Little Otter R	LOR1	0.982	0.982	0.982	**0.982**	0.983	0.985	0.987	0.990	0.991	**0.992**	0.987	0.983
Wells Creek	WEL	0.986	0.985	0.984	**0.984**	0.988	0.991	0.994	1.001	1.004	**1.006**	0.995	0.988
Johns Creek	JHN	0.905	0.902	0.901	**0.901**	0.910	0.920	0.929	0.947	0.956	**0.963**	0.932	0.911
Upper Little Otter R	LOR2	0.967	0.965	0.964	**0.964**	0.970	0.976	0.981	0.992	0.998	**1.001**	0.983	0.970

* July values represent the maximum composite ET coefficients during the growing season.
** Jan values represent the minimum composite ET coefficients during the dormant season.

Table 5-15. GWLF Land Use Parameters – Little Otter River and Buffalo Creek

Landuse	Buffalo Creek TMDL				Little Otter River TMDL							
	Lower Buffalo Creek (BWA1)		Upper Buffalo Creek (BWA2)		Lower Little Otter R (LOR1)		Wells Creek (WEL)		Johns Creek (JHN)		Upper Little Otter R (LOR2)	
	KLSCP	CN	KLSCP	CN	KLSCP	CN	KLSCP	CN	KLSCP	CN	KLSCP	CN
HiTill Rowcrop (hit)	0.4856	88.1	0.2685	86.1	0.3020	85.6	0.4920	86.5	0.4944	84.9	0.3328	85.2
LoTill Rowcrop (lot)	0.1026	85.6	0.0567	83.7	0.0638	83.1	0.1039	84.0	0.1044	82.5	0.0703	82.8
Pasture (pas_g)	0.0278	72.0	0.0172	70.1	0.0249	67.2	0.0436	68.8	0.0228	66.0	0.0295	66.5
Pasture (pas_f)	0.1112	79.1	0.0689	77.2	0.0998	75.5	0.1744	76.8	0.0913	74.6	0.1182	75.0
Pasture (pas_p)	0.1974	88.4	0.1222	86.5	0.1771	86.0	0.3096	86.9	0.1621	85.4	0.2097	85.7
Riparian pasture (trp)	1.6931	88.4	1.0515	86.5	1.5147	86.0	2.5269	86.9	1.3880	85.4	1.7511	85.7
AFO (afo)	0.0000	97.9	0.0000	96.2	0.0000	98.3	0.0000	98.3	0.0000	98.3	0.0000	98.3
Hay (hay)	0.0599	78.7	0.0411	76.8	0.0607	75.4	0.0653	76.6	0.0578	74.6	0.0536	74.9
Forest (for)	0.0050	70.9	0.0027	69.0	0.0048	66.1	0.0044	67.8	0.0038	64.9	0.0045	65.4
Harvested forest (hvf)	0.0501	76.4	0.0267	74.5	0.0485	72.4	0.0440	73.8	0.0379	71.4	0.0448	71.8
Transitional (barren)	1.5307	94.9	0.7954	93.0	1.3354	93.4	1.2917	94.0	1.0930	92.9	1.1760	93.1
Pervious LDI (pur_LDI)	0.0221	79.1	0.0139	77.2	0.0185	75.5	0.0199	76.8	0.0187	74.6	0.0190	75.0
Pervious MDI (pur_MDI)	0.0067	79.1	0.0095	77.2	0.0153	75.5	0.0253	76.8	0.0158	74.6	0.0160	75.0
Pervious HDI (pur_HDI)	0.0038	79.1	0.0102	77.2	0.0133	75.5	0.0253	76.8	0.0144	74.6	0.0182	75.0
Impervious LDI (imp_LDI)	0.0000	97.2	0.0000	95.3	0.0000	96.4	0.0000	96.8	0.0000	96.2	0.0000	96.3
Impervious MDI (imp_MDI)	0.0000	99.7	0.0000	97.8	0.0000	100.0	0.0000	100.0	0.0000	100.0	0.0000	100.0
Impervious HDI (imp_HDI)	0.0000	99.7	0.0000	97.8	0.0000	100.0	0.0000	100.0	0.0000	100.0	0.0000	100.0

LDI = low intensity developed; MDI = medium intensity developed; HDI = high intensity developed

Table 5-16. GWLF Watershed Parameters for Comparison and Calibration Watersheds

GWLF Watershed Parameters	units	Comparison Watersheds				Calibration
		BLD	BNF	CNT	GCR	BOR1x
recession coefficient	(day^{-1})	0.0485	0.1201	0.0521	0.0918	0.0488
seepage coefficient		0.0400	0.0400	0.0400	0.0400	0.0400
leakage coefficient		0.0150	0.0150	0.0150	0.0150	0.0150
sediment delivery ratio		0.0809	0.1785	0.0998	0.1675	0.0831
unsaturated water capacity	(cm)	15.80	13.30	14.58	10.56	14.79
erosivity coefficient (Nov - Apr)		0.117	0.139	0.120	0.127	0.102
erosivity coefficient (growing season)		0.211	0.244	0.212	0.209	0.186
% developed land	(%)	0.1	0.0	0.2	0.0	0.1
no. of livestock	(AU)	2,036	0	883	26	345
area-weighted runoff curve number		73.28	71.59	69.51	65.66	69.57
area-weighted soil erodibility		0.315	0.333	0.271	0.239	0.290
area-weighted slope	(%)	23.50	35.80	11.63	31.52	28.59
aFactor		0.0000759	0.0000890	0.0000423	0.0000393	0.0000673
total stream length	(m)	147,752.0	8,235.0	129,417.0	7,894.0	38,064.0
Mean Channel Depth	(m)	2.028	0.802	1.641	0.928	1.162

Table 5-17. GWLF Monthly ET Cover Coefficients – Comparison and Calibration Watersheds

Watershed	ID	Apr	May	Jun	Jul*	Aug	Sep	Oct	Nov	Dec	Jan**	Feb	Mar
Buffalo Creek	BLD	0.994	0.994	0.994	**0.994**	0.993	0.992	0.991	0.989	0.988	**0.988**	0.991	0.993
N.F. Buffalo River	BNF	0.998	0.999	1.000	**1.000**	0.994	0.989	0.984	0.973	0.967	**0.963**	0.982	0.994
Big Chestnut Creek	CNT	0.993	0.994	0.994	**0.994**	0.991	0.988	0.984	0.978	0.974	**0.972**	0.983	0.991
Green Creek	GCR	0.997	0.999	0.999	**0.999**	0.995	0.990	0.986	0.977	0.973	**0.970**	0.984	0.994
Big Otter River	BOR1x	0.993	0.993	0.993	**0.993**	0.992	0.990	0.989	0.985	0.984	**0.983**	0.988	0.992

* July values represent the maximum composite ET coefficients during the growing season.
** Jan values represent the minimum composite ET coefficients during the dormant season.

Table 5-18. GWLF Land Use Parameters – Comparison and Calibration Watersheds

	Comparison Watersheds								Calibration	
Landuse	Buffalo Creek		N.F. Buffalo		Big Chestnut		Green Creek		Big Otter River	
	KLSCP	CN	KLSCP	CN	KLSCP	CN	KLSCP	CN	KLSCP	CN
HiTill Rowcrop (hit)	0.3608	85.1	2.1019	88.5	0.3788	85.8	0.1161	84.9	0.3899	85.6
LoTill Rowcrop (lot)	0.0876	84.3	0.4439	86.1	0.0800	83.3	0.0245	82.4	0.0823	83.1
Pasture (pas_g)	0.0500	71.8	0.0906	72.5	0.0207	67.6	0.0207	65.9	0.0354	67.2
Pasture (pas_f)	0.2001	79.1	0.3624	79.6	0.0827	75.8	0.0829	74.5	0.1416	75.5
Pasture (pas_p)	0.3552	88.5	0.6432	88.9	0.1468	86.2	0.1472	85.3	0.2513	86.0
Riparian pasture (trp)	2.9571	88.5	4.3487	88.9	1.2653	86.2	1.2605	85.3	2.0909	86.0
AFO (afo)	0.0000	98.3	0.0000	98.3	0.0000	98.3	0.0000	98.3	0.0000	98.3
Hay (hay)	0.1225	78.6	0.2809	79.1	0.0507	75.7	0.0557	74.5	0.0628	75.4
Forest (for)	0.0110	70.7	0.0136	71.4	0.0051	66.5	0.0095	64.8	0.0080	66.1
Harvested forest (hvf)	0.1099	76.3	0.1365	76.9	0.0506	72.7	0.0946	71.3	0.0800	72.4
Transitional (barren)	3.4282	95.1	4.6205	95.4	1.5228	93.5	3.1387	92.9	2.3614	93.4
Pervious LDI (pur_LDI)	0.0466	79.1	0.0738	79.6	0.0196	75.8	0.0611	74.5	0.0293	75.5
Pervious MDI (pur_MDI)	0.0548	79.1	0.0906	79.6	0.0225	75.8	0.0611	74.5	0.0155	75.5
Pervious HDI (pur_HDI)	0.0137	79.1	0.0906	79.6	0.0282	75.8	0.0611	74.5	0.0405	75.5
Impervious LDI (imp_LDI)	0.0000	97.4	0.0000	97.6	0.0000	96.5	0.0000	96.1	0.0000	96.4
Impervious MDI (imp_MDI)	0.0000	100.0	0.0000	100.0	0.0000	100.0	0.0000	100.0	0.0000	100.0
Impervious HDI (imp_HDI)	0.0000	100.0	0.0000	100.0	0.0000	100.0	0.0000	100.0	0.0000	100.0

LDI = low intensity developed; MDI = medium intensity developed; HDI = high intensity developed

Chapter 6: TMDLS AND ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that appropriate actions can be taken to achieve water quality standards (USEPA, 1991). The stressor analysis in each of the Buffalo Creek and Little Otter River watersheds Creek indicated that sediment was the "most probable stressor", and therefore, sediment will serve as the basis for development of these TMDLs.

In addition to the sediment stressor, nutrients were also identified as an additional stressor in the Lower Little Otter River. Since the source of the excess nutrients is the Bedford City water treatment plant, which sits just upstream of this segment, this impairment will be addressed through the normal VPDES effluent permitting process.

6.1. Setting TMDL Endpoints and MOS using the AllForX Approach

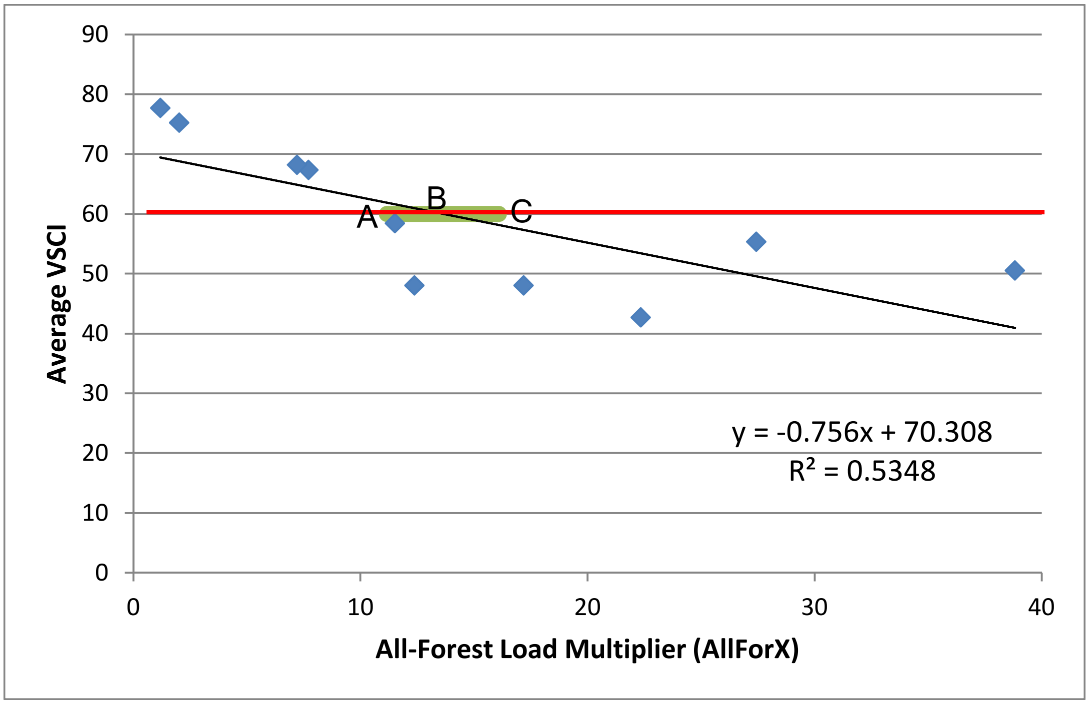
In the AllForX approach, introduced in Chapter 4, the metric used for setting a numeric sediment threshold is the All-Forest Load Multiplier (AllForX) calculated as the existing sediment load normalized by the corresponding load under an all-forest condition. AllForX is calculated as the existing sediment load in any given watershed divided by the corresponding sediment load simulated under an all-forest condition. When AllForX is regressed against VSCI for a number of healthy watersheds surrounding a particular impaired watershed or set of impaired watersheds, the developed relationship can be used to quantify the value of AllForX for the biological health threshold (VSCI < 60) used to assess aquatic life use impairments in Virginia. The sediment TMDL load is then calculated as the value of AllForX at the VSCI threshold times the all-forest sediment load of the impaired watershed. Since a number of watersheds are used to quantify the regression, a confidence interval around the threshold was used to quantify the margin of safety in the Total Maximum Daily Load equation.

Existing sediment loads were calculated for each of the watersheds contributing to the six (6) impaired segments in this study and for each of the four (4) comparison watersheds. A modeling scenario was then created and run, which substituted forest land use-related parameters for each of the other land uses, while preserving the unique characteristics of soil and slope distributions across each watershed. AllForX was then calculated by dividing the existing sediment load by the all-forest load. The modeling results for each watershed are summarized as long-term averages for each watershed in Table 6-1.

Table 6-1. Metrics used in the AllForX Approach

	Impaired Watersheds						Comparison Watersheds			
	BWA1	**BWA2**	**LOR1**	**WEL**	**JHN**	**LOR2**	**BLD**	**BNF**	**CNT**	**GCR**
	Sediment Load in tons/yr									
Existing Sediment Load	3,370.8	1,597.4	9,527.3	3,458.8	616.3	7,035.3	24,801.8	472.6	7,982.0	983.3
All-Forested Sediment Load	292.4	71.5	769.1	89.1	35.8	256.4	0.0	3,210.9	398.6	1,106.4
AllForX*	**11.5**	**22.3**	**12.4**	**38.8**	**17.2**	**27.4**	**7.7**	**1.2**	**7.2**	**2.0**
Average VSCI	**58.4**	**42.7**	**48.0**	**50.5**	**48.0**	**55.3**	**67.3**	**77.7**	**68.2**	**75.2**

A regression between AllForX and VSCI was developed using all ten (10) watersheds, as shown in Figure 6-1. The value of AllForX used to set the sediment TMDL load was the value where the regression line crossed the biological impairment threshold of VSCI = 60 (AllForX = 13.64), indicated by point B. The TMDL load for each watershed was calculated as its All-Forest sediment load times the threshold AllForX value (13.64). An 80% confidence interval was then calculated around the point where the regression line intersects the biological impairment threshold (VSCI = 60). The margin of safety (MOS) was calculated as the All-Forest sediment load times the difference in AllForX between the point where the regression crosses VSCI = 60 (AllForX = 13.64) and the lower bound of the 80% confidence interval (AllForX = 11.17). Note that the MOS is equal to this difference expressed as a percentage of the threshold AllForX, and therefore is the same for all watersheds using this regression. Existing, TMDL, and MOS loads are shown in Table 6-2 for each impaired segment. Since the MOS is a measure of uncertainty in the TMDL, the implementation target load is the TMDL minus the MOS, and the percent reduction is calculated as the change from the future load to the allocation target load.



B = AllForX value used for the TMDL; AC = the 80% Confidence Interval (shown in green);
B - A = AllForX value used for the MOS; A = AllForX value used for the target allocation load.

Figure 6-1. Regression and AllForX Threshold for Sediment in Little Otter and Buffalo Creek

Table 6-2. Calculation of the TMDL and MOS for each Impaired Segment

	Impaired Watersheds					
	BWA1	**BWA2**	**LOR1**	**WEL**	**JHN**	**LOR2**
	Sediment Load in tons/yr					
Future Sediment Load	3,672.4	1,632.0	9,526.5	3,458.8	615.9	6,395.5
All-Forested Sediment Load	292.4	71.5	769.1	89.1	35.8	256.4
TMDL Load (AllForX = 13.64)	**3,987.4**	**974.8**	**10,487.3**	**1,214.7**	**488.8**	**3,496.4**
Margin of Safety (MOS)*	**721.3**	**176.3**	**1,897.0**	**219.7**	**88.4**	**632.5**
MOS as % of TMDL	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%
Allocation Load (TMDL - MOS)	**3,266.1**	**798.5**	**8,590.3**	**995.0**	**400.4**	**2,864.0**
% Reduction from Future Load:	11.1%	51.1%	9.8%	71.2%	35.0%	55.2%

* MOS = ($AllForX_{13.64}$ - $AllForX_{11.17}$) * All-Forest Load

The relationship between AllForX and the biological condition was further validated with the following plots and regressions between AllForX and various independent sediment-related habitat metrics: average habitat sediment deposition in Figure 6-2; average epifaunal substrate in Figure 6-3; and total habitat score in Figure 6-4.

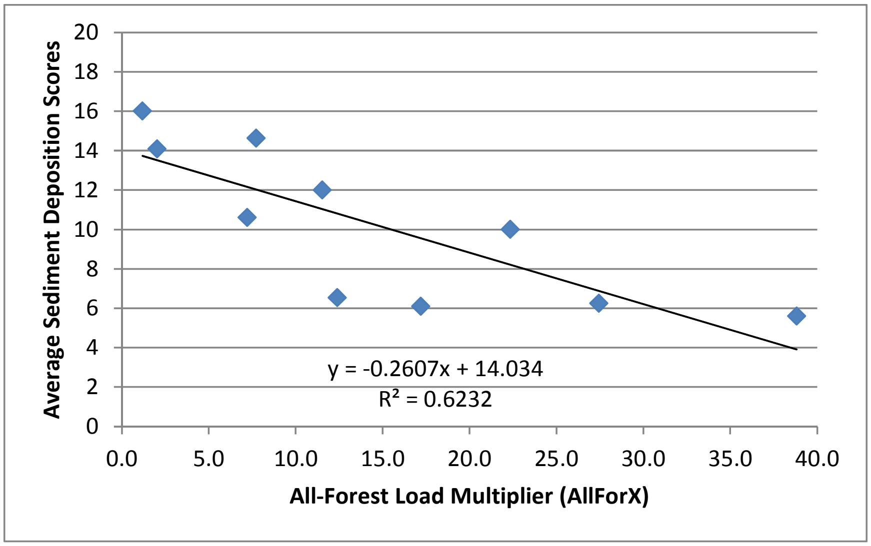


Figure 6-2. AllForX vs. Average Habitat Sediment Deposition Scores

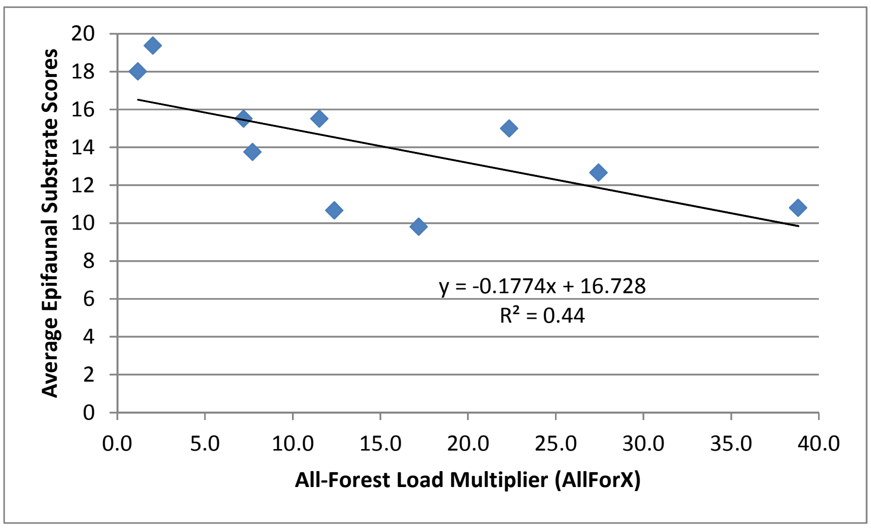


Figure 6-3. AllForX vs. Average Habitat Epifaunal Substrate Scores

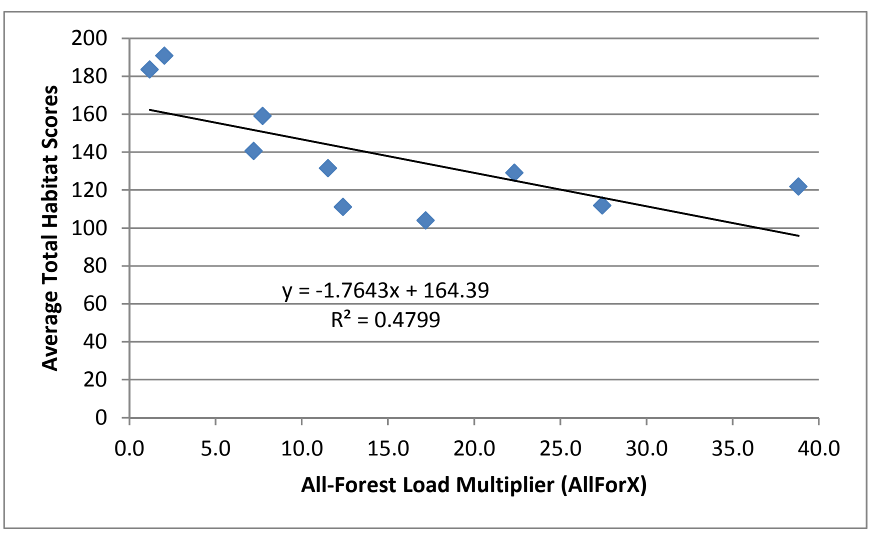


Figure 6-4. AllForX vs. Average Total Habitat Scores

6.2. Buffalo Creek and Little Otter River Sediment TMDLs

6.2.1. TMDL Components

The sediment TMDL for each of the Buffalo Creek and Little Otter River watersheds was calculated using the following equation:

TMDL = ∑WLA + ∑LA + MOS

where ∑WLA = sum of the wasteload (permitted) allocations;

∑LA = sum of load (nonpoint source) allocations; and

MOS = margin of safety.

The TMDL sediment loads for each impaired watershed were calculated using the AllForX method described in the previous section.

The WLA in each watershed is comprised of sediment loads from a number of individual industrial stormwater, municipal, and commercial permitted sources, as well as aggregated loads from construction runoff in each watershed. In addition, a Future Growth WLA was calculated as a portion of existing WLAs in each watershed, excluding construction, plus a portion of existing WWTP WLAs, with a minimum allowance of 0.1% of the TMDL.

An explicit MOS was calculated for each impaired watershed also using the AllForX method.

The LA was calculated as the TMDL minus the sum of WLA and MOS. The TMDL load and its components for each impaired watershed are shown in Table 6-3.

Table 6-3. Buffalo Creek and Little Otter River Sediment TMDLs

Impairment	TMDL	WLA		LA	MOS
	(tons/yr)				
Cause Group Code L27R-02-BEN					
Lower Buffalo Creek	3,987.4	11.45		3,254.6	721.3
VAC-L27R_BWA02A02		VAR051801 New London Auto Parts Inc	3.64 tons/yr		
VAC-L27R_BWA01A00		construction aggregate WLA	0.53 tons/yr		
		Future Growth WLA	7.28 tons/yr		
Upper Buffalo Creek	974.8	22.99		775.4	176.3
		VAR040115 Virginia DOT MS-4 WLA	6.95 tons/yr		
		construction aggregate WLA	2.13 tons/yr		
		Future Growth WLA	13.91 tons/yr		
Cause Group Code L26R-01-BEN					
Lower Little Otter River	10,487.3	34.50		8,555.9	1,897.0
VAW-L26R_LOR01A00		VAR051233 Bedford County - Sanitary Landfill	11.22 tons/yr		
VAW-L26R_LOR02A00		construction aggregate WLA	0.84 tons/yr		
VAW-L26R_LOR03A00		Future Growth WLA	22.45 tons/yr		
Upper Little Otter River	3,496.4	158.23		2,705.7	632.5
VAW-L26R_LOR04A00		VA0022390 Bedford City - WWTP	91.38 tons/yr		
		VAG640066 Bedford City - WTP	1.51 tons/yr		
		VAR050544 Hilltop Lumber Co Inc	2.56 tons/yr		
		VAR052107 Central VA Pallet and Stake Co	2.53 tons/yr		
		construction aggregate WLA	1.36 tons/yr		
		Future Growth WLA	58.89 tons/yr		
Cause Group Code L26R-02-BEN					
Johns Creek	488.8	32.12		368.3	88.4
VAW-L26R_JHN01A00		VAG110014 Bedford Ready Mix Concrete	0.33 tons/yr		
		VAR050528 Sam Moore Furniture LLC	4.32 tons/yr		
		VAR050733 Rubatex International LLC	1.57 tons/yr		
		VAR051369 Bedford City - Hylton Site	4.32 tons/yr		
		construction aggregate WLA	0.53 tons/yr		
		Future Growth WLA	21.06 tons/yr		
Cause Group Code L26R-03-BEN					
Wells Creek	1,214.7	1.40		993.6	219.7
VAW-L26R_WEL01A02		VA0020818 Body Camp Elementary School	0.1 tons/yr		
		construction aggregate WLA	0.09 tons/yr		
		Future Growth WLA	1.21 tons/yr		

6.2.2. Maximum Daily Loads

The USEPA (2006a) has mandated that TMDL studies submitted since 2007 include a maximum "daily" load (MDL), in addition to the average annual loads shown in Section 6.2.1. The approach used to develop these MDLs was provided in Appendix B of a related USEPA guidance document (USEPA, 2006b). This appendix entitled "Approaches for developing a Daily Load Expression for TMDLs computed for Longer Term Averages" is dated December 15, 2006. This guidance provides a procedure for calculating an MDL (tons/day) for each watershed and pollutant from the long-term average (LTA) annual TMDL load (tons/yr) and a coefficient of variation (CV) based on annual loads over a period of time. The "LTA to MDL multipliers" for Buffalo Creek and Little Otter River were calculated from the 1992-2010 simulated output of annual sediment loads using the calibrated GWLF model.

Annual simulated sediment loads for Buffalo Creek ranged from 1,549 to 15,911 tons/yr, producing a coefficient of variation (CV) = 0.61. The "LTA to MDL" multiplier was then interpolated from the USEPA guidance and calculated as 5.609 for both impaired Buffalo Creek sub-watersheds. The MDL was calculated as the TMDL divided by 365 days/yr and multiplied by 5.609.

Annual simulated sediment loads for Little Otter River ranged from 5,840 to 49,009 tons/yr, producing a coefficient of variation (CV) = 0.47. The "LTA to MDL" multiplier was then interpolated from the USEPA guidance and calculated as 4.453 for all four impaired Little Otter Creek sub-watersheds. The MDL was calculated as the TMDL divided by 365 days/yr and multiplied by 4.453.

Since the WLA represents permitted loads, no multiplier was applied to these loads. Therefore the daily WLA and components were converted to daily loads by dividing by 365 days/yr. The daily LA was calculated as the MDL minus the daily WLA minus the daily MOS. The resulting sediment MDL and associated components for the two Buffalo Creek segments and the six Little Otter Creek segments are shown in Table 6-4 in units of tons/day.

Expressing the TMDL as a daily load does not interfere with a permit writer's authority under the regulations to translate that daily load into the appropriate permit limitation, which in turn could be expressed as an hourly, weekly, monthly or other measure (USEPA, 2006a).

Table 6-4. Buffalo Creek and Little Otter River Maximum "Daily" Sediment Loads

Impairment	MDL	WLA		LA	MOS
	(tons/day)				
Cause Group Code L27R-02-BEN					
Lower Buffalo Creek	61.28	0.031		50.16	11.08
VAC-L27R_BWA02A02		VAR051801 New London Auto Parts Inc	0.01 tons/day		
VAC-L27R_BWA01A00		construction aggregate WLA	0.001 tons/day		
		Future Growth WLA	0.02 tons/day		
Upper Buffalo Creek	14.98	0.063		12.21	2.71
		VAR040115 Virginia DOT MS-4 WLA	0.019 tons/day		
		construction aggregate WLA	0.006 tons/day		
		Future Growth WLA	0.038 tons/day		
Cause Group Code L26R-01-BEN					
Lower Little Otter River	127.96	0.094		104.72	23.14
VAW-L26R_LOR01A00		VAR051233 Bedford County - Sanitary Landfill	0.031 tons/day		
VAW-L26R_LOR02A00		construction aggregate WLA	0.002 tons/day		
VAW-L26R_LOR03A00		Future Growth WLA	0.061 tons/day		
Upper Little Otter River	42.66	0.433		34.51	7.72
VAW-L26R_LOR04A00		VA0022390 Bedford City - WWTP	0.25 tons/day		
		VAG640066 Bedford City - WTP	0.004 tons/day		
		VAR050544 Hilltop Lumber Co Inc	0.007 tons/day		
		VAR052107 Central VA Pallet and Stake Co	0.007 tons/day		
		construction aggregate WLA	0.004 tons/day		
		Future Growth WLA	0.161 tons/day		
Cause Group Code L26R-02-BEN					
Johns Creek	5.96	0.087		4.80	1.08
VAW-L26R_JHN01A00		VAG110014 Bedford Ready Mix Concrete	0.001 tons/day		
		VAR050528 Sam Moore Furniture LLC	0.012 tons/day		
		VAR050733 Rubatex International LLC	0.004 tons/day		
		VAR051369 Bedford City - Hylton Site	0.012 tons/day		
		construction aggregate WLA	0.001 tons/day		
		Future Growth WLA	0.058 tons/day		
Cause Group Code L26R-03-BEN					
Wells Creek	14.82	0.004		12.13	2.69
VAW-L26R_WEL01A02		VA0020818 Body Camp Elementary School	0.0003 tons/day		
		construction aggregate WLA	0.0002 tons/day		
		Future Growth WLA	0.003 tons/day		

6.3. Allocation Scenarios

The target allocation sediment load for each watershed allocation scenario is the TMDL minus the MOS. Allocation scenarios were created by applying percent reductions to the various land use/source categories until the target allocation load was achieved for each of the Buffalo Creek and Little Otter River watersheds.

Two allocation scenarios were created for each of the watersheds. Scenario 1 applies equal percent reductions from all land uses and sources, except forest and point sources. Scenario 2 applies equal percent reductions from only the two largest sources in each watershed. The preferred scenario for each watershed will be determined by the local Technical Advisory Committee. Future sediment loads along with two allocation scenarios are presented by grouped land uses and sources for the Lower Buffalo Creek in Table 6-5; Upper Buffalo Creek in Table 6-6; for the Lower Little Otter River in Table 6-7; for Johns Creek in Table 6-8; for Wells Creek in Table 6-9; and for the Upper Little Otter River in Table 6-10.

Table 6-5. Sediment TMDL Load Allocation Scenario, Lower Buffalo Creek

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	13.9	11.4%	12.3		13.9
Pasture	2,407.3	11.4%	2,131.7	13.1%	2,092.7
Hay	284.8	11.4%	252.2		284.8
Forest	118.4		118.4		118.4
Harvested Forest	10.9	11.4%	9.7		10.9
Developed	702.6	11.4%	622.2	13.1%	610.8
Channel Erosion	130.5	11.4%	115.5		130.5
Permitted WLA	4.2		4.2		4.2
Total Load	3,672.4		**3,266.1**		**3,266.1**
Target Allocation Load	**3,266.1**				
% Reduction Needed	11.1%				

Table 6-6. Sediment TMDL Load Allocation Scenario, Upper Buffalo Creek

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	52.4	52.1%	25.1		52.4
Pasture	970.4	52.1%	464.5	60.2%	385.9
Hay	145.1	52.1%	69.4		145.1
Forest	24.1		24.1		24.1
Harvested Forest	2.2	52.1%	1.1		2.2
Developed	413.3	52.1%	197.8	60.2%	164.3
Channel Erosion	15.4	52.1%	7.4		15.4
Permitted WLA	9.1		9.1		9.1
Total Load	1,632.0		**798.5**		**798.5**
Target Allocation Load	**798.5**				
% Reduction Needed	51.1%				

Table 6-7. Sediment TMDL Load Allocation Scenario, Lower Little Otter River

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	193.8	10.0%	174.4		193.8
Pasture	7,019.9	10.0%	6,315.8	12.3%	6,155.0
Hay	1,223.6	10.0%	1,100.9		1,223.6
Forest	180.4		180.4		180.4
Harvested Forest	15.9	10.0%	14.3		15.9
Developed	578.7	10.0%	520.7	12.3%	507.4
Channel Erosion	302.2	10.0%	271.9		302.2
Permitted WLA	12.1		12.1		12.1
Total Load	9,526.5		**8,590.3**		**8,590.3**
Target Allocation Load	**8,590.3**				
% Reduction Needed	9.8%				

Table 6-8. Sediment TMDL Load Allocation Scenario, Johns Creek

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	8.1	36.4%	5.2		8.1
Pasture	285.4	36.4%	181.5	40.9%	168.7
Hay	46.3	36.4%	29.4		46.3
Forest	13.1		13.1		13.1
Harvested Forest	1.2	36.4%	0.8		1.2
Developed	241.6	36.4%	153.6	40.9%	142.8
Channel Erosion	9.2	36.4%	5.9		9.2
Permitted WLA	11.1		11.1		11.1
Total Load	615.9		**400.4**		**400.4**
Target Allocation Load	**400.4**				
% Reduction Needed	35.0%				

Table 6-9. Sediment TMDL Load Allocation Scenario, Wells Creek

Land Use/ Source Group	Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	3.6	71.6%	1.0		3.6
Pasture	3,087.0	71.6%	875.8	78.9%	651.8
Hay	308.5	71.6%	87.5		308.5
Forest	18.9		18.9		18.9
Harvested Forest	1.7	71.6%	0.5		1.7
Developed	36.3	71.6%	10.3	78.9%	7.7
Channel Erosion	2.7	71.6%	0.8		2.7
Permitted WLA	0.2		0.2		0.2
Total Load	3,458.8		**995.0**		**995.0**
Target Allocation Load	**995.0**				
% Reduction Needed :	71.2%				

Table 6-10. Sediment TMDL Load Allocation Scenario, Upper Little Otter River

Land Use/ Source Group	Future Sediment Load (tons/yr)	Scenario 1		Scenario 2	
		% Reduction	Load	% Reduction	Load
Row Crops	13.2	56.8%	5.7		13.2
Pasture	4,706.9	56.8%	2,031.2	63.6%	1,715.0
Hay	578.7	56.8%	249.7		578.7
Forest	83.9		83.9		83.9
Harvested Forest	7.7	56.8%	3.3		7.7
Developed	848.9	56.8%	366.3	63.6%	309.3
Channel Erosion	56.9	56.8%	24.5		56.9
Permitted WLA	99.3		99.3		99.3
Total Load	6,395.5		**2,864.0**		**2,864.0**
Target Allocation Load	**2,864.0**				
% Reduction Needed :	55.2%				

6.4. Lower Little Otter Creek Nutrient Impairment

Nutrients have been diagnosed as one of the most probable stressors in the Lower Little Otter River. Specifically, between DEQ monitoring stations 4ALOR014.75 and 4ALOR014.33, average total nitrogen increases from 0.9 to 3.4 mg/L and average total phosphorus increases from 0.1 to 0.7 mg/L. The most apparent source of these nutrients is the discharge from a permitted point source, VA0022390 - the Bedford City wastewater treatment plant. Frequent exceedences of the in-stream TP threshold of 0.2

mg/L have been noted at the downstream DEQ monitoring station, although TP is not one of the permit parameters required at the effluent outfall.

The Little Otter River is a tributary to Smith Mountain Lake, and as such is subject to regulation 9VAC25-40-30 for "nutrient enriched waters" outside of the Chesapeake Bay Watershed. All dischargers in these waters authorized by VPDES permits for discharges of 1.0 MGD or more are required to meet a monthly average total phosphorus effluent limitation of 2.0 mg/l.

Since the source of the nutrient stressors in the Lower Little Otter River is related to a permitted source, a TMDL will not be developed for TN and TP, but the impairment will instead be addressed through the permitting process. Additional effluent monitoring is recommended to ensure compliance with the “nutrient enriched waters” limitation.

Chapter 7: TMDL IMPLEMENTATION

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairments on Buffalo Creek, Johns Creek, Wells Creek, and the Little Otter River. The second step is to develop a TMDL Implementation Plan. The final step is to implement the TMDL Implementation Plan and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by USEPA and then the State Water Control Board (SWCB), measures must be taken to reduce pollutant levels in the stream. These measures, which can include the use of better treatment technology and the installation of BMPs, are implemented in an iterative process that is described along with specific BMPs in the Implementation Plan. The process for developing an Implementation Plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/ipguide.pdf. With successful completion of Implementation Plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved Implementation Plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

Watershed stakeholders will have opportunity to participate in the development of the TMDL Implementation Plan, which is the next step in the TMDL process. Specific goals for BMP implementation will be established as part of the Implementation Plan development. DCR and DEQ will work closely with watershed stakeholders, interested state agencies, and support groups to develop an acceptable Implementation Plan that will result in meeting the water quality target. Stream delisting of Buffalo Creek and Little

Otter River impaired stream segments will be based on biological health and not on numerical pollution loads.

7.1. Link to ongoing Restoration Efforts

Implementation of BMPs to address the benthic impairments in Buffalo Creek and Little Otter River will be coordinated with BMPs required to meet bacteria water quality standards in a previous TMDL developed for the Big Otter River watershed, which includes both Buffalo Creek and Little Otter River.

7.2. Reasonable Assurance for Implementation

7.2.1. TMDL Monitoring

DEQ will monitor benthic macro-invertebrates and habitat in accordance with its biological monitoring program, and TSS in accordance with its ambient monitoring program at station 4ALOR014.75 in the Upper Little Otter River, at station 4AJHN000.01 in Johns Creek, at station 4AWEL001.14 in Wells Creek, at station 4ALOR014.33 in the Lower Little Otter River, at station 4ABWA008.53 in the Upper Buffalo Creek, and at station 4ABWA002.00 in the Lower Buffalo Creek. In the past, all of these stations have been used for both biological and ambient sampling, with the exception of stations 4ALOR014.33 and station 4ABWA008.53 which were monitored regularly for benthic macro-invertebrates and habitat, but only periodically for ambient parameters. DEQ will add bi-monthly sampling of ambient TSS at these two stations and will continue to use data from all of these monitoring stations to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

7.2.2. Regulatory Framework

<u>Federal Regulations</u>

While section 303(d) of the Clean Water Act and current USEPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Federal regulations also require that all new or revised

National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to USEPA for review.

State Regulations

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. USEPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and implementation plan development, especially those implemented through water quality based effluent limitations. However, those requirements that are considered BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the identified impairment. New permitted point source discharges will be allowed under the waste load allocation provided they implement applicable VPDES requirements.

7.2.3. Implementation Funding Sources

Implementation funding sources will be determined during the implementation planning process by the local watershed stakeholder planning group with assistance from DEQ and DCR. Potential sources of funding include Section 319 funding for Virginia's Nonpoint Source Management Program, the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund, although other sources are also available for specific projects and regions of the state. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

7.2.4. Reasonable Assurance Summary

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act’s Section 303(e). In response to a Memorandum of Understanding (MOU) between USEPA and DEQ, DEQ also submitted a draft Continuous Planning Process to USEPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Taken together, the follow-up monitoring, WQMIRA, public participation, the Continuing Planning Process, and the reductions called for in the concurrent bacteria TMDL on the Big Otter River comprise a reasonable assurance that the Buffalo Creek, Johns Creek, Wells Creek, and Little Otter River sediment TMDLs will be implemented and water quality will be restored.

Chapter 8: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made.

The first Technical Advisory Committee Meeting was held from 10:00 am until noon on June 21, 2012 at the Bedford Central Library in Bedford, Virginia. The purpose of that meeting was to introduce agency stakeholders to the TMDL process and to discuss the impairments identified on stream segments in these watersheds. The public meeting was attended by 19 people. Many of the attendees reconvened after lunch to participate in a watershed tour, conducted by personnel from the Peaks of Otter Soil and Water Conservation District and NRCS personal.

The first Public Meeting was held at 7:00 – 9:00 pm at the Forest Library in Forest, Virginia on August 14, 2012, where the TMDL process was introduced, local stream impairments were presented, and comments were solicited from the stakeholder group. The first public meeting was attended by 18 people.

A second Technical Advisory Committee meeting was held from 2:00 – 4:00 pm on October 18, 2012, at the Bedford Central Library in Bedford. The results from the stressor analysis were presented, and comments were solicited from the stakeholder group. The second TAC meeting was attended by 9 people.

A third Technical Advisory Committee meeting is planned for February 7, 2013 to present modeling procedures, draft modeling results, and to solicit feedback on the proposed TMDL strategy.

A final public meeting is planned for February 20, 2013 to present the draft TMDL report to address benthic impairments in the Little Otter River and Buffalo Creek watersheds. This final TMDL public meeting was attended by xx stakeholders. The public comment period will end on March xx, 2013.

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Appendix A: Glossary of Terms

Allocation
That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario
A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

Best Management Practices (BMP)
Methods, measures, or practices that are determined to be reasonable and cost- effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Hydrology
The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Load allocation (LA)
The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)
A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model
Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Nonpoint source
Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Point source
Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution
Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach
Segment of a stream or river.

Runoff
That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Simulation
The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Total Maximum Daily Load (TMDL)
The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff
Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Wasteload allocation (WLA)
The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard
Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed
A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.
http://www.ext.vt.edu/pubs/bse/442-758/442-758.html

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.
http://www.ext.vt.edu/pubs/bse/442-550/442-550.html.

Appendix B: Detailed Land Use Distributions

Table B-1. Modeled Land Use Distributions for Existing Conditions in Little Otter River

Modeled Land Use Categories	Lower Little Otter River	Machine Creek	Wells Creek	Johns Creek	Upper Little Otter River	Entire Little Otter River
	(area in hectares					
HiTill Rowcrop (hit)	24.80	47.35	1.23	2.51	5.45	81.34
LoTill Rowcrop (lot)	20.86	39.83	1.03	2.11	4.58	68.41
Pasture (pas_g)	106.44	188.23	62.31	11.91	170.33	539.22
Pasture (pas_f)	745.06	1317.61	436.17	83.36	1192.31	3774.52
Pasture (pas_p)	212.87	376.46	124.62	23.82	340.66	1078.43
Riparian pasture (trp)	56.01	99.05	32.79	6.27	89.63	283.74
AFO (afo)	6.56	11.60	3.84	0.73	10.50	33.23
Hay (hay)	557.51	971.69	321.66	62.38	892.18	2805.41
Forest (for)	1507.00	2240.31	355.40	390.65	1953.92	6447.29
Harvested forest (hvf)	15.22	22.63	3.59	3.95	19.74	65.12
Transitional (barren)	1.48	1.69	0.34	1.99	5.12	10.61
Pervious Low Intensity Developed (pur_LDI)	340.97	408.13	81.94	372.69	1123.81	2327.55
Pervious Med Intensity Developed (pur_MDI)	7.02	0.88	0.00	48.51	51.59	108.00
Pervious High Intensity Developed (pur_HDI)	0.33	0.07	0.00	5.40	3.36	9.15
Impervious LDI (imp_LDI)	15.05	11.97	1.77	27.36	61.49	117.64
Impervious MDI (imp_MDI)	3.01	0.38	0.00	20.79	22.11	46.29
Impervious HDI (imp_HDI)	1.24	0.25	0.00	20.32	12.63	34.44
Total Area	**3,621.4**	**5,738.1**	**1,426.7**	**1,084.7**	**5,959.4**	**17,830.4**

Table B-2. Modeled Land Use Distributions for Existing Conditions in Buffalo Creek

Modeled Land Use Categories	Lower Buffalo Creek	Upper Buffalo Creek	Entire Buffalo Creek
	(area in hectares)		
HiTill Rowcrop (hit)	1.48	11.87	13.35
LoTill Rowcrop (lot)	1.24	9.98	11.23
Pasture (pas_g)	60.81	52.02	112.82
Pasture (pas_f)	425.66	364.12	789.77
Pasture (pas_p)	121.62	104.03	225.65
Riparian pasture (trp)	32.00	27.37	59.37
AFO (afo)	3.75	3.21	6.95
Hay (hay)	312.02	266.91	578.93
Forest (for)	2234.32	969.06	3203.38
Harvested forest (hvf)	22.57	9.79	32.36
Transitional (barren)	2.12	8.48	10.60
Pervious Low Intensity Developed (pur_LDI)	256.06	922.34	1178.40
Pervious Med Intensity Developed (pur_MDI)	0.88	50.93	51.81
Pervious High Intensity Developed (pur_HDI)	0.13	2.83	2.96
Impervious LDI (imp_LDI)	4.93	42.60	47.53
Impervious MDI (imp_MDI)	0.38	21.83	22.20
Impervious HDI (imp_HDI)	0.50	10.65	11.15
Total Area	**3,480.5**	**2,878.0**	**6,358.5**

Table B-3. Modeled Land Use Distributions for Future Conditions in Little Otter River

Modeled Land Use Categories	Lower Little Otter River	Machine Creek	Wells Creek	Johns Creek	Upper Little Otter River	Entire Little Otter River
	(area in hectares)					
HiTill Rowcrop (hit)	23.81	47.35	1.23	2.51	5.01	79.91
LoTill Rowcrop (lot)	20.02	39.83	1.03	2.11	4.22	67.21
Pasture (pas_g)	102.18	188.23	62.31	11.91	156.70	521.33
Pasture (pas_f)	715.25	1317.61	436.17	83.36	1096.93	3649.33
Pasture (pas_p)	204.36	376.46	124.62	23.82	313.41	1042.67
Riparian pasture (trp)	53.77	99.05	32.79	6.27	82.46	274.33
AFO (afo)	6.30	11.60	3.84	0.73	9.66	32.13
Hay (hay)	535.21	971.69	321.66	62.38	820.80	2711.74
Forest (for)	1446.72	2240.31	355.40	390.65	1797.61	6230.70
Harvested forest (hvf)	14.61	22.63	3.59	3.95	18.16	62.94
Transitional (barren)	2.00	1.69	0.34	1.99	6.62	12.63
Pervious Low Intensity Developed (pur_LDI)	461.15	408.13	81.94	372.69	1452.45	2776.36
Pervious Med Intensity Developed (pur_MDI)	9.50	0.88	0.00	48.51	66.67	125.57
Pervious High Intensity Developed (pur_HDI)	0.45	0.07	0.00	5.40	4.34	10.25
Impervious LDI (imp_LDI)	20.36	11.97	1.77	27.36	79.47	140.92
Impervious MDI (imp_MDI)	4.07	0.38	0.00	20.79	28.57	53.81
Impervious HDI (imp_HDI)	1.68	0.25	0.00	20.32	16.33	38.57
Total Area	**3,621.4**	**5,738.1**	**1,426.7**	**1,084.7**	**5,959.4**	**17,830.4**

Table B-4. Modeled Land Use Distributions for Future Conditions in Buffalo Creek

Modeled Land Use Categories	Lower Buffalo Creek	Upper Buffalo Creek	Entire Buffalo Creek
	(area in hectares)		
HiTill Rowcrop (hit)	1.18	10.68	11.87
LoTill Rowcrop (lot)	1.00	8.98	9.98
Pasture (pas_g)	48.65	46.82	95.46
Pasture (pas_f)	340.52	327.71	668.23
Pasture (pas_p)	97.29	93.63	190.92
Riparian pasture (trp)	25.60	24.63	50.23
AFO (afo)	3.00	2.88	5.88
Hay (hay)	249.62	240.22	489.84
Forest (for)	1787.46	872.15	2659.61
Harvested forest (hvf)	18.06	8.81	26.86
Transitional (barren)	7.26	9.93	17.20
Pervious Low Intensity Developed (pur_LDI)	877.48	1080.61	1958.09
Pervious Med Intensity Developed (pur_MDI)	3.01	59.67	62.68
Pervious High Intensity Developed (pur_HDI)	0.45	3.32	3.77
Impervious LDI (imp_LDI)	16.89	49.91	66.80
Impervious MDI (imp_MDI)	1.29	25.57	26.86
Impervious HDI (imp_HDI)	1.70	12.48	14.18
Total Area	**3,480.5**	**2,878.0**	**6,358.5**

Appendix C: Detailed Simulated Sediment Loads

Table C-1. Simulated Sediment Loads for Existing Conditions in Little Otter River Watershed

Land Use/Source Categories	Lower Little Otter River	Machine Creek	Wells Creek	Johns Creek	Upper Little Otter
	Sediment Load (tons/yr)				
HiTill Rowcrop (hit)	96.7	76.1	1.8	4.7	8.0
LoTill Rowcrop (lot)	92.2	72.9	1.7	4.5	7.7
Pasture (pas_g)	65.8	28.9	32.5	3.1	53.4
Pasture (pas_f)	2,368.4	1,078.4	1,060.2	109.8	1,887.9
Pasture (pas_p)	1,363.3	622.1	608.8	63.9	1,087.7
Riparian pasture (trp)	3,320.7	1,551.4	1,385.5	144.0	2,576.1
AFO (afo)	0.0	0.0	0.0	0.0	0.0
Hay (hay)	1,259.1	782.2	308.5	52.0	689.1
Forest (for)	184.4	98.6	18.9	16.4	97.6
Harvested forest (hvf)	16.2	8.9	1.7	1.5	8.9
Transitional (barren)	152.6	53.4	11.9	59.6	165.6
Pervious LDI (pur_LDI)	198.8	102.9	23.8	95.1	299.3
Pervious MDI (pur_MDI)	1.6	0.3	0.0	7.9	8.6
Pervious HDI (pur_HDI)	0.0	0.0	0.0	1.1	0.9
Impervious LDI (imp_LDI)	40.3	6.6	0.7	9.7	30.3
Impervious MDI (imp_MDI)	47.3	0.7	0.0	26.7	38.8
Impervious HDI (imp_HDI)	13.6	0.2	0.0	10.0	8.5
Channel Erosion	306.4	38.4	2.7	6.4	55.4
Point Sources	0.0	0.0	0.0	0.0	11.6
Total Sediment Load	**9,527.3**	**4,522.1**	**3,458.8**	**616.3**	**7,035.3**

Table C-2. Simulated Sediment Loads for Existing Conditions in Buffalo Creek Watershed

Land Use/Source Categories	Lower Buffalo Creek	Upper Buffalo Creek
	Sediment Load (tons/yr)	
HiTill Rowcrop (hit)	12.2	44.7
LoTill Rowcrop (lot)	2.1	7.7
Pasture (pas_g)	24.7	9.4
Pasture (pas_f)	869.2	332.0
Pasture (pas_p)	492.6	192.1
Riparian pasture (trp)	1,124.3	436.8
AFO (afo)	0.0	0.0
Hay (hay)	298.0	145.1
Forest (for)	145.8	26.8
Harvested forest (hvf)	13.4	2.5
Transitional (barren)	259.7	169.2
Pervious LDI (pur_LDI)	76.8	163.6
Pervious MDI (pur_MDI)	0.2	4.6
Pervious HDI (pur_HDI)	0.0	0.4
Impervious LDI (imp_LDI)	9.0	16.8
Impervious MDI (imp_MDI)	10.4	26.5
Impervious HDI (imp_HDI)	2.2	4.9
Channel Erosion	30.2	14.3
Point Sources	0.0	0.0
Total Sediment Load	**3,370.8**	**1,597.4**

Table C-3. Simulated Sediment Loads for Future Conditions in Little Otter River Watershed

Land Use/Source Categories	Lower Little Otter River	Machine Creek	Wells Creek	Johns Creek	Upper Little Otter River
	Sediment Load (tons/yr)				
HiTill Rowcrop (hit)	99.2	73.8	1.8	4.2	6.7
LoTill Rowcrop (lot)	94.6	70.8	1.7	4.0	6.5
Pasture (pas_g)	65.0	27.5	32.5	2.8	44.9
Pasture (pas_f)	2,342.6	1,030.2	1,060.2	97.7	1,585.4
Pasture (pas_p)	1,348.6	594.3	608.8	56.9	913.4
Riparian pasture (trp)	3,263.6	1,485.2	1,385.5	128.1	2,163.3
AFO (afo)	0.0	0.0	0.0	0.0	0.0
Hay (hay)	1,223.6	757.6	308.5	46.3	578.7
Forest (for)	180.4	96.6	18.9	13.1	83.9
Harvested forest (hvf)	15.9	8.7	1.7	1.2	7.7
Transitional (barren)	195.8	70.6	11.9	71.1	255.3
Pervious LDI (pur_LDI)	248.4	127.9	23.8	106.0	459.7
Pervious MDI (pur_MDI)	1.8	0.4	0.0	9.5	13.4
Pervious HDI (pur_HDI)	0.0	0.1	0.0	1.3	1.3
Impervious LDI (imp_LDI)	53.6	6.4	0.7	9.7	45.9
Impervious MDI (imp_MDI)	61.6	0.9	0.0	32.0	60.2
Impervious HDI (imp_HDI)	17.5	0.2	0.0	12.0	13.2
Channel Erosion	302.2	34.6	2.7	9.2	56.9
Permitted WLA	12.1	11.7	0.2	11.1	99.3
Total Sediment Load	**9,526.5**	**4,397.5**	**3,458.8**	**615.9**	**6,395.5**

Table C-4. Simulated Sediment Loads for Future Conditions in Buffalo Creek Watershed

Land Use/Source Categories	Lower Buffalo Creek	Upper Buffalo Creek
	Sediment Load (tons/yr)	
HiTill Rowcrop (hit)	11.8	44.7
LoTill Rowcrop (lot)	2.1	7.7
Pasture (pas_g)	23.7	9.4
Pasture (pas_f)	833.5	332.0
Pasture (pas_p)	472.3	192.1
Riparian pasture (trp)	1,077.8	436.9
AFO (afo)	0.0	0.0
Hay (hay)	284.8	145.1
Forest (for)	118.4	24.1
Harvested forest (hvf)	10.9	2.2
Transitional (barren)	469.6	182.7
Pervious LDI (pur_LDI)	194.3	178.3
Pervious MDI (pur_MDI)	3.8	1.5
Pervious HDI (pur_HDI)	0.1	0.5
Impervious LDI (imp_LDI)	14.9	18.2
Impervious MDI (imp_MDI)	16.2	25.5
Impervious HDI (imp_HDI)	3.6	6.6
Channel Erosion	130.5	15.4
Permitted WLA	4.2	9.1
Total Sediment Load	**3,672.4**	**1,632.0**